REDACTED VERSION

Soil Feasibility Study Report
Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma
EPA Identification No. OK0001010917

Remedial Investigation/Feasibility Study
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LIST OF ACRONYMS AND ABBREVIATIONS

µg/L	Microgram(s) per liter
ARAR	Applicable or relevant and appropriate requirement
bgs	Below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cm/s	Centimeter per second
COC	Chemical of concern
COPC	Chemical of potential concern
CSM	Conceptual site model
EA	EA Engineering, Science, and Technology, Inc., PBC
EPA	U.S. Environmental Protection Agency
ERA	Ecological Risk Assessment
FS	Feasibility Study
ft	Foot (feet)
GRA	General Response Action
HDPE	High density polyethylene
HHRA	Human Health Risk Assessment
IC	Institutional control
ISB	In situ enhanced bioremediation
ISCO	In situ chemical oxidation
ISS	In situ stabilization and solidification
LIF	Laser-induced fluorescence
LNAPL	Light non-aqueous phase liquid
LTU	Land treatment units
LUC	Land use control
MCL	Maximum contaminant level
mg/kg	Milligram(s) per kilogram
mil	Milli-inch
MNA	Monitored natural attenuation
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFA	No further action
NPL	National Priorities List

LIST OF ACRONYMS AND ABBREVIATIONS (CONTINUED)

OAC	Oklahoma Administrative Code
ODEQ	Oklahoma Department of Environmental Quality
OSWER	Office of Solid Waste and Emergency Response
PAH	Polycyclic aromatic hydrocarbon
PRG	Preliminary remediation goal
RA	Remedial Alternatives
RAC	Remedial Action Contract
RACER	Remedial Action Cost Engineering and Requirements
RAO	Remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	Remedial investigation
ROD	Record of Decision
ROST	Rapid Optical Scanning Tool
RSL	Regional screening level
Site	Wilcox Oil Superfund Site
SLERA	Screening Level Ecological Risk Assessment
SVOC	Semivolatile organic compound
TBC	To be considered
TMV	Toxicity, mobility, or volume
VOC	Volatile organic compound
XRF	X-ray fluorescence

1 INTRODUCTION

EA Engineering, Science, and Technology, Inc., PBC (EA) has prepared this Feasibility Study (FS) Report for the U.S. Environmental Protection Agency (EPA) for the Wilcox Oil Company Superfund Site (site) in Bristow, Creek County, Oklahoma (Figure 1-1) under Remedial Action Contract (RAC) Number EP-W-06-004 and Task Order 0128-RICO-06GG. This report addresses contamination in soils at the site. The groundwater contamination is in investigation and will be addressed in a separate report.

EA prepared this report based on the Remedial Investigation (RI) Report, Revision 02 (EA 2020a), Human Health Risk Assessment, Revision 03 (EA 2020b), and Screening Level Ecological Risk Assessment, Revision 01 (EA 2020c), and in accordance with regulations and guidance documents that include, but are not limited to, the following:

- National Oil and Hazardous Substance Pollution Contingency Plan (NCP), 40 Code of Federal Regulations (CFR) Part 300

- *Guidance for Conducting Remedial Investigation and Feasibility Studies under Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), Office of Solid Waste and Emergency Response [OSWER] Directive 9355.3-01 (EPA 1988)

This FS was drafted to generally follow the framework of EPA Guidance for Conducting RIs and FS under CERCLA (EPA 1988).

1.1 PURPOSE AND SCOPE

The purpose of this report is to support a selection of remedies for the soil contamination at the site by:

- Proposing the remedial action objectives (RAOs)

- Defining specific preliminary remediation goals (PRGs)

- Developing and analyzing a range of remedial alternatives (RA).

1.2 REPORT ORGANIZATION

This FS is divided into the following chapters:

- ***Chapter 1, Introduction***—Presents the purpose of this FS Report and its organization.

- ***Chapter 2, Site Description and Background***—Provides a summary of the site history, results of RI, human health risk assessments (HHRAs) and ecological risk assessments (ERAs), site conceptual site model, and potential groundwater remedial technologies.

- ***Chapter 3, Remedial Action Objectives***—Defines RAOs, proposes PRGs, and identifies the applicable or relevant and appropriate requirements (ARARs) for the site.

- ***Chapter 4, Development and Screening of Technologies***—Identifies and screens various potential remedial technologies and options that may be used to address contaminant of concern (COC)-impacted soil.

- ***Chapter 5, Development of Remedial Alternatives***—Presents the remedial alternatives and the components of each alternative.

- ***Chapter 6, Evaluation of Remedial Alternatives***—Presents the detailed analysis and comparative analysis of the alternatives.

- ***Chapter 7, References***—Provides the list of references used in this report.

2 SITE DESCRIPTION AND BACKGROUND

2.1 SITE DESCRIPTION

The Wilcox Oil Company site is an abandoned and demolished oil refinery and associated tank farm located north of Bristow, Creek County, Oklahoma (Figure 1-1). It is situated by Route 66 to the west; a residential area and Turner Turnpike to the north and northwest; Sand Creek to the west and southwest; and residential, agricultural, and wooded areas to the east and south. The approximate geographic coordinates for the site are 35°50’31” North latitude and 96°23’02” West longitude (EA 2020a). The site spans approximately 140 to 150 acres and has been divided into five (5) major former operational areas (Figure 2-1):

- The Wilcox Process Area
- The Lorraine Process Area
- The East Tank Farm
- The North Tank Farm, and
- The Loading Dock Area.

Previous activities associated with the facility operations had caused site contamination. Some refinery waste is still present at the site but is fenced and secured to deter trespassing and potential contact with the waste.

The Wilcox Process Area is approximately 26 acres in size and is fenced. Most of the equipment and storage tanks used in the past were auctioned and/or salvaged by private land owners; any remaining structures are in ruins. Four aboveground storage tanks, a number of discarded drums and pieces of scrap iron and piping remain at the site. A former lead additive area is barren and located at the southwest portion of the Wilcox Process Area. There are multiple areas of stressed vegetation, barren soil, and visible black tarry waste of a hydrocarbon nature. Buildings in the northern and eastern parts of the former refinery were used as residences and are therefore considered as such, although they are currently vacant. An intermittent creek (West Tributary) flows southward across the eastern portion of the refinery process area through a small pond in the southeast corner of the Wilcox Process Area into Sand Creek. Hydrocarbon waste has also been observed in several drainage channels that empty into Sand Creek.

The Lorraine Process Area spans approximately 8 acres and is to the west of the Wilcox Process Area across the railroad tracks. No refinery structures remain in the area. The First Assembly of God Church (currently vacant), a playground, and a vacant residence (parsonage) are located in this area. Sand Creek borders the western boundary of the area. A drainage feature is located near the northwestern corner of the former process area that drains south into Sand Creek. Similar to the Wilcox Process Area, there are multiple areas of stressed vegetation, barren soil, and visible, black tarry waste present in the area.

The East Tank Farm is located to the east of the Wilcox Process Area and spans approximately 80 acres. The area includes pits, ponds, and a number of circular berms that surrounded former tank locations. All of the former crude oil storage tanks have been removed; however, remnants of the former tank locations remain visible. It is not known if underground piping associated with the tanks remains in place or was removed. Many of the berms surrounding the pits, ponds, and former tanks have been breached or leveled. Of the three residential properties, two are occupied and are located on or directly next to former tank locations in the East Tank Farm. There are multiple areas of stressed vegetation, barren soil, and visible black tarry waste. The East Tributary is located along the eastern boundary of the East Tank Farm and perennially flows south through a series of ponds to Sand Creek.

Magellan Midstream Partners, LP operates a pumping station in the north-central portion of the East Tank Farm Area, as well as an active pipeline that transects the East Tank Farm, Loading Dock, and North Tank Farm Areas from the southeast to the northwest. Magellan Midstream Partners, LP pumped several different petroleum products through the active pipeline, including kerosene, gasoline, jet fuel, and diesel.

The North Tank Farm is located north of Refinery Road and west of the railroad tracks and spans approximately 20 acres. All of the tanks and other structures that were used to support Lorraine Refinery to the south have been removed. An occupied residence is located in the center of the North Tank Farm. There are areas of stressed vegetation, and visible black tarry waste is present.

The Loading Dock Area spans approximately 7 acres and is located north of the Wilcox Process Area and east of the North Tank Farm and railroad tracks. The Loading Dock Area was used for loading and unloading product by rail. There are multiple areas of stressed vegetation, barren soil, and visible black tarry waste of a hydrocarbon nature, similar to the rest of site.

2.2 SITE HISTORY

The property was used for oil refinery operations from 1915 until November 1963. A modern oil refinery plant was constructed in 1929. The upgraded facility consisted of a skimming plant, cracking unit, and re-distillation battery with a vapor recovery system and treatment equipment. The Wilcox Oil Company expanded when it acquired the Lorraine Refinery in 1937 and sold the property to a private individual in 1963. Most of the equipment and storage tanks were auctioned or salvaged for scrap metal by the new property owners. Wilcox Oil Company currently no longer operates in Oklahoma. Based on information from the Oklahoma Secretary of States' office, the company merged with Tenneco Oil Company in 1967. On 24 May 2013, EPA proposed the site to the National Priorities List (NPL). On 12 December 2013, the site officially became a Federal Superfund site (EPA Identification No. OK0001010917), when it was added to the NPL.

2.2.1 Previous Investigation and Removal Activities

The EPA and Oklahoma Department of Environmental Quality (ODEQ) have conducted multiple investigations at the site since 1994. The details of the investigations can be found in the individual documents listed in the RI Report (EA 2020a).

In September and October 2017, EPA conducted a removal action and removed oily sludge and contaminated soils from a residential property at the site. Approximately 1,329 tons of oil impacted soils and sludge were removed and disposed offsite (Weston 2017). The area was backfilled with clean soil and graded and reseeded.

2.2.2 Source Control Record of Decision Summary

A Source Control Record of Decision (ROD) Summary was issued in September 2018. The ROD addresses the refinery tank waste and the lead additive area source materials through excavation, treatment, and offsite disposal (EPA 2018). The remaining risks and threats posed by the site contamination, as indicated in the Source Control ROD will be addressed in a separate document. Therefore, this FS Report provides support for the remedy decision document for the soil.

2.3 SURFACE FEATURES

The site topography slopes to the southwest and southeast with sandstone outcrops throughout. The railroad tracks run through the western portion of the site, and divides the North Tank Farm and Loading Dock Area; and Wilcox Process and Lorraine Process Areas. Several drainage features are present at the site. West Tributary, an intermittent stream, is located at the eastern side of the Wilcox Process Area; East Tributary, a perennial stream and five ponds are located at the East Tank Farm; and several drainage channels transect the property east of the railroad. All streams and channels flow to the south to Sand Creek (EA 2020a) at the southern and southwestern boundaries of the site. Sand Creek meanders approximately 3.5 miles south and east from the site until it merges with Little Deep Fork Creek.

A wetland survey was conducted in September 2016 and identified 4 wetland areas at the site (EA 2017) (Figure 2-2). Two wetlands are located in Wilcox Process Area and one in the North and one in the East Tank Farms. Among the 4 wetlands, 3 are connected with Sand Creek, which are Wetland 2 in the Wilcox Process Area associated with the West Tributary, Wetland 3 in North Tank Farm with vegetated drainage ditches to Sand Creek, and Wetland 4 in East Tank Farm along the East Tributary. Wetland 1 in the Wilcox Process Area, however is not directly connected with any tributaries and appears to obtain water from surficial runoff (EA 2017).

There are seven residential buildings/houses at the site, one in the North Tank Farm, one in the Loading Dock Area, two in the Wilcox Process Area, and three in the East Tank Farm. The houses in the Wilcox Process Area and Loading Dock Area are currently not occupied and the rest are occupied. A church and a playground are located in the Loading Dock Area.

Staining of the soil, black tarry waste, stressed vegetation, and barren areas are present throughout the site. Storage tanks, refinery-related debris and piping still remain in the Wilcox Process Area as well as the former tank berms that were cut and leveled in the East Tank Farm (EA 2020a).

2.4 FUTURE LAND AND GROUNDWATER USE

The seven residential buildings and houses are considered as residential use in this FS. The rest of the site is unused or used to graze livestock, and future plans for the property are unknown. Therefore, the site is assumed in this FS to be limited to residential use except the mid- and southern portion of the Wilcox Process Area, which consists of remaining refinery structures and features, and its future use will be industrial and commercial.

Areas in the north portion of the Lorraine Process and Wilcox Process Areas are currently on public water supply, which is supplied by 4 wells that are approximately 400 feet (ft) deep in the Vamoose-Ada aquifer. Residences located on or near the East Tank Farm obtain water from the Barnsdall Formation which is much shallower than the Vamoose-Ada aquifer (EA 2020a).

2.5 GEOLOGY AND HYDROGEOLOGY

The site is situated on the Pennsylvanian-aged Barnsdall Formation, which is composed of fine-grained sandstone overlain by shale. Thickness of the Barnsdall formation ranges from 80 to 200 ft. (ODEQ 2008) but is approximately 200 ft. thick at the site. Sandstone outcrops of the Barnsdall Formation are common throughout the site. The underlying Pennsylvanian-aged Wann Formation and underlying Iola Limestone are exposed approximately 0.25 miles to the southeast of the former refinery. The Wann Formation varies in thickness from 40 to 180 ft and is comprised of shale and fine- to medium-grained sandstone. The Iola Limestone ranges in thickness from 15 to 20 ft and consists of a calcareous fine-grained sandstone and limestone with some shale and underlies the Wann Formation. Sand Creek, located approximately 0.25 miles to the southeast of the former refinery, is associated with Quaternary-aged alluvial deposits consisting of sand, silt, clay, and lenticular beds of gravel. Thickness in these deposits ranges from 5 to 50 ft (25 ft average). Because Sand Creek borders the site to the south, localized alluvium may be present (ODEQ 2009).

The Barnsdall Formation is a bedrock aquifer and is not considered a principal groundwater resource by the Oklahoma State Department of Health (ODEQ 1994). It consists of massive-to-thin beds of coarse-to-fine grain sandstone, irregularly interbedded with sandy to silty shale. Under the Barnsdall Formation lies the Vamoosa-Ada aquifer in close proximity to the west of the site. The Vamoose-Ada aquifer is an important central Oklahoma regional drinking water aquifer (E&E 1999), which is the source for the public water supply in the area.

The shallowest regional water-bearing formation in the upper part of the Barnsdall Formation is unconfined and is overlain by the unconfined shallow perched groundwater zone. The Barnsdall Formation potentially receives groundwater recharge from precipitation and infiltration from the perched groundwater zones. Depths to seasonal perched groundwater zones are less than 10 ft and depth to groundwater ranged from 4.84 to 15.97 ft below ground surface (bgs) in the groundwater monitoring wells installed at the Lorraine and Wilcox Process Areas. The shallowest regional water-bearing formation (associated with the Barnsdall Formation) is reportedly less than 25 ft bgs (ODEQ 1994). The primary groundwater flow path for the perched groundwater zone is to the south towards Sand Creek. Figure 2-3 present a potentiometric surface map based on 2018 data. The local gradient averages approximately 0.021 foot per foot across this portion of the site.

2.6 REMEDIAL INVESTIGATION RESULT SUMMARY

The RI was conducted during a series of eight field events that occurred from August 2016 through August 2020. A total of 437 surface soil samples, 391 subsurface soil samples, 44 sediment samples, 56 surface water samples, and 35 groundwater samples were collected during the sampling events. A geophysical survey, a Rapid Optical Scanning Tool (ROST) laser-induced fluorescence (LIF) survey, and a field-portable X-ray fluorescence (XRF) survey across portions of Wilcox and Lorraine Process Areas and the East Tank Farm were conducted for the 2016 Trip Report. A passive soil gas survey and vapor intrusion sampling were also conducted in 2016. In addition, waste characterization sampling was conducted at 16 locations as well as at excavated test pits where waste was visibly present (EA 2020a).

The RI results indicated that the site soil, sediment, surface water, and groundwater have been impacted by the refinery operations. Chemicals that exceed the human health and/or ecological screening levels include:

- Soil, sediment, and groundwater: Polycyclic aromatic hydrocarbon (PAHs) / semivolatile organic compound (SVOCs), volatile organic compound (VOCs), and metals

- Surface water: PAHs and metals

Indoor air samples exceeded the screening levels but it was determined, that the exceedances are not site-related but due to previous housekeeping when the residence was occupied.

These chemicals of potential concern (COPCs) were evaluated in the HHRA and the Screening Level Ecological Risk Assessment (SLERA). The COPCs with cancer risks greater than 10^{-6} and non-cancer hazards greater than 1 were evaluated to determine if unacceptable risks posted by the COPCs are presented at the site and if additional remedial action is required (EA 2020a). This section summarizes the site overall RI results and risk assessment results. The RI Report (EA 2020a) provides more details of the investigation.

2.6.1 Waste Materials

Most of the waste at the site is relatively shallow. The waste materials encountered consisted primarily of surficial, crusted tar-like materials, in some cases flowable tar-like material, black stained soil, and oily soil.

The waste samples collected at the site and test pits were used to determine treatment and disposal alternatives for the waste materials under the Source Control ROD (EPA 2018). Therefore, the waste materials are not included in this FS. Soil with lead concentrations exceeding 800 milligrams per kilogram (mg/kg) will be removed during the removal action.

Since the remaining materials and impacted soil may still post unacceptable levels of risks under the current and future land use, they will be addressed in the FS.

2.6.2 Soil

The HHRA identified that there are human health concerns under current and future land use for exposure to site COCs, primarily benzo(a)pyrene, in the soil hot spots in the East Tank Farm and Wilcox Process Area. There are also risks for exposure to lead in the surface soil of the Lorraine and Wilcox Process Areas.

The SLERA found that the metals (chromium, copper, lead, vanadium, and zinc) in the surface soil pose risks to terrestrial plants in the Wilcox Process and Lorraine Process Areas. Metals, including chromium, manganese, and vanadium, in the surface soil in the North and East Tank Farms and Loading Dock Area also pose risks to terrestrial plants.

Surface soil contains concentrations of chromium, copper, mercury, isopropylbenene and xylenes, posing risks to soil invertebrates at the site. Lead has been found in surface soil in the two process areas, posing risks to terrestrial mammals. Surface soil lead, copper, and vanadium pose risks to terrestrial birds as well.

2.6.3 Sediment and Surface Water

Based on the findings of the HHRA, there were no human health concerns for exposure to surface water and sediment within Sand Creek and its tributaries, and onsite and nearby ponds that were sampled during the RI.

However, the SLERA found that cadmium, lead, and benzo(a)pyrene in the surface water of the ponds may pose risks to aquatic organisms. Total PAHs and manganese in sediment and surface water in Sand Creek and its tributaries also pose risks to aquatic and benthic organisms.

2.6.4 Groundwater

The HHRA identified that there were potential risks for exposure to the groundwater associated with the perched shallow groundwater unit, primarily in the Wilcox Process Area.

Due to the limited groundwater data available, it was determined that a data gap investigation would be required to evaluate the site groundwater conditions. Therefore additional groundwater investigation was conducted in August 2020. Temporary wells were installed and groundwater samples were collected at old and new monitoring wells, temporary wells, and water wells. Aquifer tests were performed at existing monitoring wells to evaluate site-specific hydraulic parameters. Groundwater levels were gauged and a survey of Sand Creek was conducted to evaluate potential communication between groundwater and the creek. The data gap investigation results are summarized in the Technical Memorandum on Data Gap Investigation (Appendix A).

Light non-aqueous phase liquid (LNAPL) was present in the soil cores at multiple locations in the Wilcox and Lorraine Process Areas during the temporary well installation in August 2020. Depths of the LNAPL ranged from 7 ft to 17 ft bgs and depths for sheens and soil staining associated with LNAPL went to 30 ft bgs (Appendix A). Although present in the soil cores, LNAPL was not observed in all of the temporary wells in the August 2020 sampling event. Existing well MW-4 in the Wilcox Process Area was the only well that contained measurable LNAPL in August 2020. Based on the RI Report (EA 2020a), MW-4 did not contain LNAPL in the 2018 sampling event although LNAPL was present in the soil cores from the well installation in the same year. In addition, during RI activities in 2016, approximately 6 ft of LNAPL was observed in GW-10 in the Lorraine Process Area and approximately 8 gallons of LNAPL was bailed from the well on 14 and 15 September 2016. But after one week of the bailing, 0.14 feet of LNAPL was observed in GW-10 on 22 September 2016. The well, which was plugged and abandoned in 2017 was located to the west of LPA-SB-17 and to the north of LPA-GW-01, of which the soil cores contained sheen and product, respectively. Movement of LNAPL to wells is affected by and related to the characteristics of LNAPL, conductivity of porous media, hydraulic gradient, capillary pressures, and well constructions where LNAPL is located. GW-10 was much deeper and had a longer screen than MW-4. Accumulation of LNAPL in GW-10 was relatively faster than in MW-4 two years ago. Therefore, additional gauging and sampling is needed to delineate LNAPL and evaluate its characteristics including its composition, density, viscosity and mobility in order to identify a potential remedial strategy for LNAPL at the site.

Widespread surface seeps/staining were observed along Sand Creek. Based on the groundwater and Sand Creek elevations surveyed in August 2020, the water level at MW-06, which is the closest well to the creek is approximately 7 to 8 ft higher than the creek elevation. Therefore, the groundwater may flow toward Sand Creek, and discharge as seepage on the streambank. Sand Creek at the site appears to be ephemeral and for much of the year the seeps are dry. It is not likely that the groundwater is a major source feeding to Sand Creek but instead, the creek only flows during and following periods of rainfalls. In addition, the surface water and sediment samples from Sand Creek collected during the RI did not contain concentrations of the COPCs that pose unacceptable risks to human health. No elevated COPCs were found in the closest upgradient well, MW-06 although high metal concentrations were found in the well. Elevated iron content in the groundwater is oxidized, becomes a less dissolved form and precipitates out at the streambank when it is exposed to the air or by microorganisms, leaving staining and iron red gelatinous slime at the creek bank. Slug tests conducted in August 2020 at monitoring wells as part of the data gap investigation evaluated a geometric mean hydraulic conductivity of 0.35 feet per day (ft/day), which is typical for a sandstone aquifer and much lower than the more permeable sand or silt aquifers. Therefore, the groundwater at the site which appears to slowly move through soil perched on bedrock and sandstone was not found to significantly impact Sand Creek.

Benzene, naphthalene, benzo(a)anthracene, 2-methylnphthalene, and dissolved metals (lead, arsenic, iron, cobalt, and manganese) exceeded their Maximum Contaminant Levels (MCLs) or EPA Regional Screening Levels (RSLs) in multiple groundwater wells. Benzo(a)pyrene however exceeded its MCL of 0.2 microgram per liter (µg/L) only in WPA-GW-02. The benzene plume is located in the north of the Wilcox Process Area and is not delineated to the northwest. Naphthalene and lead concentrations exceeded the respective RSL of 0.12 µg/L and MCL of 15 µg/L in both Lorraine and Wilcox Process Areas. Exceedances of arsenic and manganese are wide spread at the site. The COPC groundwater plumes are not fully delineated (Appendix A).

2.7 CONCEPTUAL SITE MODEL

The conceptual site mode (CSM) presents an overall view of the site and provides a foundation for the remedial alternative evaluation in support of remedy selection. It incorporates the site surface features, potential source areas, contaminant migration pathways, and nature and extent of contamination. Illustrations of the HHRA and SLERA CSM are presented in Figures2-4 and 2-5, respectively.

Source materials were historically released from the previous refinery operations. The source areas at the site include aboveground storage tanks, drums, scrap iron and piping, and the former lead additive area in the Wilcox Process Area; locations of previous refinery structures in the Lorraine Process Area; the remnants of former tanks and previous tank locations in the respective East and the North Tank Farms; and the Loading Dock Area where product was brought on and off the site. Most of the waste at the site is relatively shallow and primarily consists of crusted or flowable tar-like materials, black stained soil, and oily soil. The contaminants traveled from the ground surface vertically and horizontally, and have impacted soil and groundwater.

Although the majority of the waste materials will be removed under the Source Control ROD, waste and impacted soil that will remain after the removal action still pose unacceptable risks and are addressed in the FS. Soil exceedances above human health RSLs and ecological risk levels were found in all five former operational areas. The Wilcox Process Area is the most impacted area while the other operational areas contain “hot spots” associated with the former tanks and other historical facility features. Lead in the surface soil in the Lorraine and Wilcox Process Areas, and hot spots of benzo(a)pyrene in the soil in the East Tank Farm and Wilcox Process Area poses unacceptable risks to human health. Metals in the surface soil in all five operational areas also pose unacceptable ecological risks.

LNAPL as source material is primarily present and can be found in the Lorraine and Wilcox Process Areas. Although observed at only one monitoring well (MW-04) with a measurable amount, LNAPL sheen and product was present in the soil cores at multiple locations during well drilling and soil sampling. LNAPL characteristics, hydrogeological and other site conditions (i.e., capillary pressure, hydraulic conductivity, and groundwater table fluctuation) affect the LNAPL behavior and mobility at the site. The LNAPL footprint still needs to be defined. Additional gauging and sampling of the LNAPL at the existing monitoring wells is also needed to evaluate LNAPL characteristics including its composition, density, viscosity and mobility in order to identify a potential remedial strategy for LNAPL at the site.

The site lies on an unconfined shallow perched groundwater zone that overlies the Barnsdall Formation which consists of coarse-to-fine grain sandstone interbedded with sandy to silty shale.

The formation at the site seems highly heterogeneous and groundwater flows through soil perched on bedrocks to the south and southwest toward Sand Creek. Depths to seasonal perched groundwater zones are less than 10 ft and depth to groundwater ranged from 4.84 to 15.97 ft bgs in the Lorraine and Wilcox Process Areas. Approximately 2.67 ft to 3.67 ft increase in water level at MW-01 and MW-03 in Lorraine Process Area, and all three monitoring wells' water level in Wilcox Process Area was 1 to 2.5 ft lower in August 2020 than that during the December 2018 sampling event. Hydraulic conductivities ranged from 0.07 feet per day (ft/day) at MW-04 to 0.64 ft/day at MW-05 based on the slug tests conducted in August 2020 (Appendix A). The permeability of the formation at the site was relatively low based on the slug tests and temporary well purging (Appendix A). MW-02 and MW-03 did not provide sufficient volume of water for the slug test; and groundwater recovery rates were too low during the purging at temporary wells to allow water quality parameters to stabilize before samples were collected, although the small diameter of the wells (1 inch in diameter) may also play a role for the low recovery rate of groundwater.

Groundwater plumes are not fully defined. Benzene, naphthalene, benzo(a)anthracene, 2-methylnaphthalene, and metals (lead, arsenic, iron, cobalt, and manganese) exceeded MCLs or RSLs. A Benzene plume is located in the Wilcox Process Area; and naphthalene and lead are in both process areas. Compared to the lead plume, however, arsenic and manganese plumes are widespread and larger (Appendix A).

Monitored natural attenuation (MNA) parameters were collected in August 2020 to evaluate current site conditions in aspect of potential natural attenuation process. It appears the site groundwater overall as indicated in the Appendix A, is reducing and highly reducing in MW-04 and MW-01, which may be considered as source wells. Methane concentrations at the MW-01 and MW-04 were 12 mg/L and 18 mg/L respectively, much higher than non-detect to 0.28 mg/L in the downgradient wells. Nitrate was not detected and sulfate was non-detect or low in the upgradient wells (MW-01 and MW-04, respectively), and became higher in concentration in the downgradient wells. Opposite to the sulfate pattern, ferrous iron concentration, however was higher in the upgradient wells than that in the downgradient wells.

High levels of methane and carbon dioxide in the updagradient wells may potentially be resulted from degradation of the petroleum contaminants in the early stage of contamination, which produces end products such as, carbon dioxide under aerobic conditions, and methane and carbon dioxide under anaerobic conditions among other products, i.e., hydrogen, water, nitrogen, simple organic acids, and cell mass. Non-detect and low levels of nitrate and sulfate as electron acceptors in the upgradient wells or source wells may be due to their consumption by microorganisms under anaerobic conditions, when the oxygen is low or depleted. On the other hand, high concentrations of ferrous iron and dissolved manganese are present in the source / upgradient wells MW-01 and MW-4 where the groundwater is in a strong reducing condition. Metals, including iron, arsenic, and manganese typically remain bound to insoluble ferric iron oxy-hydroxide coatings in the soil matrix, but may become dissolved under reducing conditions, and that is more likely why the elevated concentrations of dissolved iron, manganese, and arsenic in the groundwater are present across the site, especially in the source wells MW-01 and MW-04.

Overall, the site condition may have been resulted from biodegradation of benzene, naphthalene, benzo(a)pyrene, and other petroleum hydrocarbons in the early stage of the contamination, and may have become reducing as currently observed. However, natural assimilative capacity of continuous degradation is unknown, and future degradation pathways are not certain, either through sulfate or nitrate reduction, or aerobic pathways because of low levels of electron acceptors, i.e., oxygen, nitrate, and sulfate especially in the source wells, MW-01 and MW-04. Typical and efficient degradation of petroleum hydrocarbons have been found to be under aerobic pathway. Therefore, additional groundwater data and contaminant concentration changes over time are required to fully understand natural attenuation potential at the site.

The site groundwater flows to the south to Sand Creek, however, the groundwater does not appear to be the main source feeding to the creek. The surface water and sediment do not pose an unacceptable risks for human health, although metals and PAHs in the surface water and sediment do pose unacceptable risks for ecological acceptors. Due to the low hydraulic conductivity of the perched groundwater unit and absence of petroleum compounds in MW-06, which is the closest well to Sand Creek, the site groundwater does not likely impact Sand Creek significantly.

2.8 POTENTIAL GROUNDWATER REMEDIAL TECHNOLOGIES

A few potential technologies for the site groundwater can be explored based on the current understanding of the site, i.e., pump-and-treat, *in situ* enhanced bioremediation (ISB); *in situ* chemical oxidation (ISCO), and *in situ* stabilization and solidification (ISS). A full evaluation of alternatives should be conducted once more data are collected.

The LNAPL's quantity, mobility and recoverability are currently not known, but if the LNAPL is found mobile and highly recoverable, potentially pump-and-treat or skimming technology can be used to recover the LNAPL for offsite disposal. Based on the LNAPL observation at MW-04, however its recovery rate is likely low and pumping may not be effective. Depending on remedial objectives, for mass control and reduction of mobility, ISS may be used to physically / chemically bind LNAPL with stabilizing reagents. However, institutional controls (ICs) should be put in place to protect the stabilized area and long term monitoring may also be necessary to monitor potential leaching of stabilized contaminants into the dissolved phase.

Similar to LNAPL, if the dissolved phase plume is massive and unstable, pump-and-treat can be used to hydraulically control the plume and treat the contaminants. However, the pump-and-treat system will need components that treat both metals and organic contaminants from the commingled plumes. Granular activated carbon or other absorbing materials can be used to treat the recovered petroleum hydrocarbons in the system, but are not effective for metals. Therefore, another treatment train shall be needed, which may include pH adjustment to precipitate metals or ion exchange system. The system can become complex and cost can be high for operation and maintenance. In addition, low recovery rates of the temporary wells and low hydraulic conductivity observed at the site may limit the cost-effectiveness of a pump-and-treat system.

ISB is an *in situ* technology to consider, and it involves injection of amendments into groundwater to stimulate aerobic biodegradation of benzene, naphthalene, and other petroleum hydrocarbons. Commercially available products of ISB amendments include the oxygen-releasing compounds by Regenesis and PermeOx by PeroxyChem. Although ISB will probably not directly address the lead, arsenic and other dissolved metals in the groundwater, added oxygen containing compounds can also react with dissolved metals, specifically dissolved iron and manganese to generate iron and manganese oxides, which can bind and precipitate lead and arsenic in the groundwater.

ISCO as another *in situ* technology involves injection of chemical oxidant amendments into the subsurface to transform contaminants in groundwater into innocuous byproducts. Common ISCO reagents include hydrogen peroxide, sodium persulfate, potassium permanganate, sodium percarbonate, and ozone. These reagents are able to efficiently oxidize a wide range of compounds including benzene, naphthalene, and other organic compounds. However, ISCO may mobilize metals, especially for redox sensitive metals, i.e., chromium, arsenic, and lead. Therefore, it is not applicable for the areas with metal exceedances to make metal plumes worse. In addition, LNAPL presence at the site may lower the effectiveness of ISCO by coating on the reagent particles and reducing reaction potential with the contaminants.

Provect-OX®, a commercial product made by Provectus Environmental Products, Inc. was found to be able to oxidize naphthalene and pentachlorophenol in the groundwater in another EPA Superfund site without increasing in metal concentrations. Provect-OX® contains persulfate (as an oxidant) and ferric iron (as an activation agent) in a single premixed package. It has found that residual iron and sulfate generated from persulfate decomposition can be used as electron acceptors for facultative reductive processes. Therefore, Provect-OX® may promote secondary enhanced bioremediation to manage residuals in the groundwater, which may be applicable to the site groundwater. A bench scale treatability study for ISCO must be conducted to determine a sufficient dosing of the oxidant to account for natural oxidant demand in the subsurface and also evaluate potential metal mobility caused by the oxidant.

Technologies that require injection target treated areas directly, so enhanced distribution of reagents is very important for improving treatment efficiency. The site's high heterogeneity may be a concern for injected reagents to be evenly distributed to the contaminated subsurface. Therefore, ISS can be an option to overcome the shortcomings at the site. During ISS, a large diameter rig is used to mix and homogenize amendments with soil/groundwater. The mixed materials allow to form a monolith with certain strength and structural integrity to hold the contaminants in place and minimize leaching to the groundwater. Typical ISS reagents include Portland cement, slag, fly ash, bentonite, organoclay, and powdered activated carbon. ISS can effectively stabilize metals and petroleum hydrocarbons in the groundwater but has found that it is not able to reduce naphthalene leaching potential in some projects. Therefore, it may be used in the source areas to significantly reduce the source contributions to the dissolved plumes. This option can address both soil and groundwater contaminated with LNAPL, metals, and organic compounds at the same time because the rig can mix reagents from unsaturated to saturated zones in one operation. A bench scale treatability study is required to develop an optimal reagent mixture prior to a full scale ISS implementation. In addition, as stated previously ICs are required to prevent any earth moving activities in the ISS treated area.

3 REMEDIAL ACTION OBJECTIVES

This section proposes RAOs and PRGs for the contaminated soils at the site. The section also discusses the ARARs and identifies areas and volumes of contaminated soils exceeding the PRGs and therefore need to be addressed in the FS.

3.1 REMEDIAL ACTION OBJECTIVES

The RAOs were developed for contaminated soils to addressed unacceptable human health risks identified through the risk assessment process. The future land use and contaminant exposure pathways were included in the RAO development. The soil RAOs are to:

- Prevent human exposure to the soils with concentrations of COCs exceeding the PRGs.

- Minimize and prevent migration of soil contaminants into the groundwater, surface water, and other site soils.

3.2 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Remedial actions must protect public health and the environment. Section 121(d) of CERCLA requires that federal and state ARARs be identified and that response actions achieve compliance with the identified ARARs. This requirement makes CERCLA response actions consistent with pertinent federal and state environmental requirements as well as adequately protecting public health and the environment. Therefore, compliance with the ARARs is included in the development and evaluation of the remedial alternatives.

3.2.1 Definition of Applicable or Relevant and Appropriate Requirements

As defined in the NCP, "applicable requirements" are cleanup standards, standards of control, criteria, or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only the state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable (40 CFR 300.5).

Relevant and appropriate requirements may not specifically apply but may address similar issues or situations that might be encountered at the site. A requirement must be either applicable or both relevant and appropriate to be selected as an ARAR.

3.2.2 Classifications of Applicable or Relevant and Appropriate Requirements

ARARs for remedial alternatives can be generally classified into the following three categories:

1. ***Chemical-Specific*** are usually based on health- or risk-based numerical values or methodologies used to determine acceptable amounts or concentrations of chemicals that

may be found in, or discharged to the environment, i.e., MCLs or State Water Quality Standards.

2. ***Location-Specific*** are restrictions placed on the concentrations of hazardous substances or activities solely because they are in certain environmentally sensitive areas. Some examples of special locations regulated under various federal laws include floodplains, wetlands, historically significant cultural resources, and sensitive ecosystems or habitats.

3. ***Action-Specific*** are usually technology- or activity-based requirements or limitations on actions or conditions involving specific substances.

In addition to these three categories, some EPA and State guidelines also need “to be considered” (TBC). The TBC are non-promulgated advisories, non-enforceable guidelines or criteria and standards useful for developing a remedial action criterion or evaluating protection of human health and / or environment. Examples include EPA reference doses and risk specific doses that may be used for determining the level of cleanup.

Table 3-1 presents the ARARs for the site. These ARARs are identified based on the site conditions and in consideration of potential remedial alternatives developed in the FS.

3.3 PRELIMINARY REMEDIATION GOALS

The soil PRGs have been developed based on future land use and results of the RI and risk assessments for the contaminated soils posing unacceptable human health and ecological risks.

The proposed PRGs for site soil COCs are listed below:

- Lead - 200 mg/kg (for residential use); and 400 mg/kg (for industrial use)
- Benzo(a)pyrene – 1.2 mg/kg (residential and industrial screening level)

It is assumed that addressing the risks to human health would resolve the ecological risks based on the future land use, which is assumed to be limited to residential use at the site, with the exception of the Wilcox Process Area where there is only one area in the north that is considered as residential and the rest of the process area is assumed as industrial and commercial use.

3.4 OCCURRENCE AND VOLUME OF SOILS ABOVE PRGS

The soils exceeding the lead PRGs are identified across the Wilcox and Lorraine Process Areas and the west of East Tank Farm. Figure 3-1 shows the exceedances. Most of the exceedances are in the surface soil, 0 to 2 ft bgs. There are two locations, one in the Lorraine Process Area and the other in the Wilcox Process Area where the lead exceedances are deeper, from 2 ft to 6 ft bgs.

The soils exceeding the benzo(a)pyrene PRG are also located in the Lorraine and Wilcox Process Areas. Some exceedances are co-located with lead exceedances and similar to the lead, benzo(a)pyrene contamination is primarily in the surface soil.

Additional sampling is needed to refine the extent of the contaminated soils, and delineation sampling will need to be conducted during the remedial design. For the purpose of this FS, the exceedance boundaries are estimated based on the assumption that a boundary line is in the midpoint between the sampling point with exceedance and the nearby sampling point of non-exceedance. The estimated area and volume of impacted soils are as follows:

- Lorraine Process Area –57,500 square feet, 113,000 cubic feet
- Wilcox Process Area – 174,000 square feet, 348,000 cubic feet
- East Tank Farm – 114,000 square feet, 228,000 cubic feet

In summary, a total of 345,500 square feet (7.9 acres) and 25,500 cubic yards of contaminated soil with concentrations above the PRGs are to be addressed by this FS (Figure 3-1).

4 DEVELOPMENT AND SCREENING OF TECHNOLOGIES

This section describes the process of development and screening of technologies. The development process starts by identifying general response actions and associated technologies for soils. The remedial technologies are then screened under the three criteria: effectiveness, implementability, and cost.

4.1 GENERAL RESPONSE ACTIONS AND REMEDIAL TECHNOLOGIES

General response actions may include institutional actions, containment, treatment, removal, disposal, or a combination of these as described in the EPA 1988 guidance (EPA 1988). As required by the NCP (40 CFR §300.430.e.6), selected remedial alternatives must include no further action (NFA) to be used as the baseline against which the effectiveness of all other alternatives are evaluated. Thus, NFA is included in the alternative evaluation for the site soil.

NFA means nothing is done to the site. NFA does not control, contain, or remediate contaminant sources, and it does not reduce the mobility, volume, or toxicity of the contamination at the site.

In addition, ICs are also included in evaluation of alternatives. ICs may include restrictions on land use, access restrictions, environmental monitoring, security measures, notification, and education advisories to inform the public and adjacent landowners about the site. Common ICs include zoning, enforceable land use restrictions (i.e., deed notice and covenant restriction), and long-term environmental monitoring.

The general response actions suitable for the site soils include following:

- NFA
- ICs
- Containment
- Removal / disposal
- Treatment.

Table 4-1 presents the general response actions and their individual technologies considered in this section.

4.2 REMEDIAL TECHNOLOGY SCREENING

This section presents and screens the remedial technologies presented in Table 4-1.

4.2.1 Preliminary Screening Criteria

Three preliminary screening criteria (i.e., effectiveness, implementability, and cost) were used to screen the remedial technologies. Definitions for these criteria are presented below.

Effectiveness is a measure of a technology's ability to: (1) reduce toxicity, mobility, or volume; (2) minimize residual risks; (3) afford long-term protection; (4) comply with ARARs; (5) minimize short-term impacts; and (6) achieve protectiveness in a limited duration. Technologies that are significantly less effective than other technologies may be eliminated from the alternative development process. Technologies that do not provide adequate protection of human health and the environment are also eliminated from further consideration.

The effectiveness evaluation is focused on the following elements:

- Potential effectiveness of technologies in handling the areas or volumes of the soil to meet the RAOs.
- Potential impacts to human health and the environment during the construction and implementation phase.
- Reliability and proven effectiveness of the technologies with respect to the COCs under site-specific conditions.

Implementability is a measure of both technical and administrative feasibility of implementing a technology process. Initial technology screening eliminates technologies that are clearly ineffective or unusable at the site. Implementability aspects include:

- Technical feasibility that may include constructability or workability under site conditions, being able to operate and maintain to meet the PRGs, and the complexity of the technology.
- Administrative feasibility that may include permitting, and accessibility (easements, rights-of-way required; access to the properties to be addressed; and ability to impose ICs).
- Availability of services and materials which may include availability of special equipment, materials and specially trained and skilled workers required, and offsite treatment and disposal capacity.

Cost (capital and operation and maintenance costs) is a measure of resources that are required in technology implementation. The costs used in this document were obtained from published resources and previous projects. Cost evaluation at the technology screening phase is relative, typically presented as high, low, or medium compared to other technologies within the same technology type. The technologies with high cost but low protection of human health and environment are not considered for further evaluation.

4.2.2 Technology Screening Summary

Table 4-1 presents the rationales for technologies retained or eliminated based on the three preliminary criteria. The soil technologies and process options retained for further evaluation include NFA, ICs, excavation, containment and disposal.

4.2.2.1 NFA (Retained)

NFA has been retained in accordance with the requirements of Subpart F of the NCP as a baseline for comparison with the other technologies.

4.2.2.2 Land Use Controls (Retained)

Land use controls (LUCs) are administrative measures developed to protect human health and safety from the presence of hazards. LUCs are measures that limit access or use of a property to protect people from site hazards or provide warnings of a potential site hazard. LUCs include engineering controls and physical barriers (e.g., fencing), educational programs (e.g., public notification of residual concerns), and administrative and legal controls (e.g., zoning restrictions and easements) that help to minimize the potential for human exposure. They have been retained for alternative development.

LUCs prohibit future residential use in the mid- and southern portion of the Wilcox Process Area and industrial land uses for the rest of the site. LUCs would be effective for reducing the potential exposure to the site soil. LUCs are implementable and costs are low, therefore, LUCs are retained.

4.2.2.3 Excavation (Retained)

Excavation can involve removal of all impacted soil and "hot spots" from a site. Excavation is a well-proven and effective method for removing impacted materials from a site to prevent direct contact and exposure to the contaminants. Therefore, it will address the relevant remedial objectives for the site. Excavation is a mature technology and easy to be implemented. Cost for excavation is low compared to other technologies. Therefore, this technology is retained for further consideration.

4.2.2.4 In Situ Treatments (Not Retained)

In situ treatment technologies treat contaminants in place. Compared to *ex situ* treatment technologies, *in situ* remedial technologies handle contaminated media in place, therefore its process of handling hazardous materials potential is low, as well as disposal costs and exposure of the contaminants to the workers.

In Situ Solidification/Stabilization

In situ solidification/stabilization processes involve adding and mixing reagents with soil to trap, treat, or immobilize contaminants. This technology is typically implemented by grouting or using a large-diameter auger or other equipment to mix with soil while adding reagents. Treated soil will become stabilized to prevent contaminants from leaching out to groundwater. Types of solidifying/stabilizing reagents include Portland cement, fly ash, blast furnace slag, bentonite, organoclay, and powdered activated carbon. Note that *ex situ* solidification/stabilization is discussed separately under *Ex Situ* Treatment section.

In situ solidification/stabilization can be effect in stabilizing the contaminated soil and reducing contaminant migration vertically and horizontally. Overall this technology will reduce the site risks and protect human health and environment. A treatability study is required prior to a full scale implementation to develop mixtures of reagents. However, the site contaminated soil is non-hazardous and is a low-level threat (not a principal threat waste) to the environment, *in situ* solidification/stabilization, or any other treatment technologies, therefore would not be cost effective compared to non-treatment technologies. In addition, ICs are required to protect the treated areas from intrusive activities, i.e., excavation, drilling and injections, which may limit future site use and development. Cost of *in situ* solidification/stabilization is high compared to other technologies. Therefore, this technology is not retained because of the high cost and waste still remaining in place at the site.

Phytoremediation

Phytoremediation is a process that uses plants to remove, transfer, stabilize and destroy contaminants in soil. There are six general approaches to phytoremediation: phytoaccumulation, phytodegradation, phytostabilization, phytovolatilization, rhizodegradation, and rhizofiltration (Interstate Technology and Regulatory Cooperation Work Group [ITRC] 1999). A variety of plants have shown limited uptake of metals and benzo(a)pyrene in surface soil. A pilot treatability study is necessary to develop ideal environmental conditions for plant growth and remediation before a full-scale implementation. Although it is relatively easy to implement, the effectiveness of phytoremediation may not be reliable and highly relies on plant types, seasonal temperature change, soil type, pH, and moisture content. In addition, phytoremediation may require an extended time period compared to several other technologies. Cost of phytoremediation is low to medium depending on needs for long-term maintenance, replanting, and monitoring. Therefore, due to unreliability and uncertainty in effectiveness this technology will be not be retained for further consideration.

4.2.2.5 Ex Situ Treatments (Not Retained)

Ex situ treatment involves the excavation and subsequent treatment of soil. The treated soil is either used as backfill within the site or taken offsite for final disposal depending on the final results of the treatment.

Landfarming

Landfarming is a bioremediation technology in which excavated soils are placed in land treatment units (LTUs) and mixed and tilled periodically to blend nutrients/amendments and water to enhance the biological activity within the LTUs. The LTUs are constructed with an impermeable liner i.e., compacted clay or high density polyethylene (HDPE) geomembrane, to protect the soil underneath the treatment area. Sprinkler systems are required for most of the cases to provide irrigation for the system (FRTR, 1997).

Landfarming typically is applicable for treatment of lighter petroleum compounds and it becomes less effective for the PAHs with more aromatic rings, i.e., benzo(a)pyrene. It is not certain with current data available if landfarming is effective for lead in soil. In addition, landfarming is easy to implement but it may require a long period of time for microorganisms to degrade or stabilize the soil COCs, although the cost is low. Therefore landfarming is eliminated from further evaluation.

Ex Situ Solidification/Stabilization

Ex situ solidification/stabilization involves excavating and mixing contaminated materials with reagents to stabilize contaminants. The *ex situ* process is typically applicable to hazardous wastes to reduce the leaching potential and remove their hazardous/toxic characteristics before offsite disposal.

Ex situ solidification/stabilization is effective for lead in soil and is implementable, but the cost may be high. Based on the site data, the majority of the site soil is non-hazardous, which would not require treatment if disposed offsite. Therefore, this technology does not provide better benefits for the soil remediation compared to non-treatment technologies, therefore it is not considered for further evaluation.

Soil Washing

Soil washing is a process using a solution of leaching, surfactant, pH-adjustment or chelating agent to remove contaminants. The wash solution with washed COCs is treated by conventional wastewater treatment methods and treated soil can typically be reused onsite or sent offsite for non-hazardous disposal. This process can also be used to separate fines from coarse materials. The majority of contaminants are sorbed to the fines, and once separated the coarse materials could be reused.

Soil washing is effective method for separating metals from soil. It is implementable with commercially available equipment. However, the process is complex and produces a large amount of wastewater, which can increase the cost significantly. Therefore, it is not considered for further evaluation.

4.2.2.6 Offsite Disposal (Retained)

Disposal includes placement of waste materials in a permanent repository that is subsequently managed to prevent reintroduction of contaminants into the environment. Waste material and contaminated soil removed from the site must be disposed of at an appropriate waste management facility.

Offsite disposal is an effective process for permanently removing impacted soil. Regulatory requirements regarding waste characteristics for the disposed soil would dictate the type of landfill facility. It is implementable and cost is at an average level compared with other technology. This option adequately addresses the RAOs, therefore this process will be retained for further consideration.

4.2.2.7 Onsite Containment (Retained)

Containment technologies control human and/or ecological exposure to COCs by preventing the migration of COCs and/or preventing direct contact with impacted media. Onsite containment includes consolidation and placement of impacted soil under a protective cover or into a containment repository constructed onsite to prevent exposure and minimize the potential migration of COCs.

An onsite containment will address the relevant remedial objectives. It is implementable but it will require ICs to protect the integrity of the repository.

5 DEVELOPMENT OF REMEDIAL ALTERNATIVES

This section presents the remedial alternatives that were retained for the site soil during the technology screening. The technologies retained were assembled to develop a range of alternatives and provide flexibility in selecting preferred alternatives. The development of the alternatives was based on the EPA's document, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988), which advises to include:

- Alternatives that permanently reduce the toxicity, mobility, or volume of contaminants. The range of alternatives should, if possible, vary in the degree of reliance on long-term management of untreated wastes

- Permanent solutions to the maximum extent practicable

- Innovative treatment technologies and resource recovery technologies to maximum extent practicable

- One or more containment alternatives that involve little or no treatment of hazardous contaminants

- A "No Action" alternative.

The following remedial alternatives were identified as potential alternatives for the soil:

- Alternative S-1: NFA
- Alternative S-2: Soil excavation and offsite disposal
- Alternative S-3: Soil excavation and onsite containment repository
- Alternative S-4: Soil excavation, and onsite consolidation and capping

Table 5-1 presents a summary of the alternatives and RAOs that each alternative potentially could achieve.

5.1 COMMON COMPONENTS FOR SOIL ALTERNATIVES

ICs will be included as components in all of the soil alternatives with the exception of NFA. Land use in the mid and southern part of the Wilcox Process Area will be restricted to industrial and commercial use.

5.2 ALTERNATIVE S-1: NO FURTHER ACTION

Alternative S-1 assumes no remedial action for soil. It is used as a baseline for comparison to other remedial alternatives as required by the NCP. Under NFA, no remedial actions will be conducted at the site and contaminated soil posing unacceptable risks would be left in place.

5.3 ALTERNATIVE S-2: SOIL EXCAVATION AND OFFSITE DISPOSAL

Alternative S-2 includes excavation of soil exceeding the PRGs and disposal of the material offsite in a Resource Conservation and Recovery Act (RCRA) permitted and licensed landfill. Figure 3-1 shows the locations of the soil exceeding the PRGs.

The main components of Alternative S-2 include:

- Pre-excavation delineation of contaminated soil exceeding the PRGs
- Site preparation including removal of vegetation in the excavation areas, setup of work zones, installation of erosion and sediment controls near the creek and associated tributaries if excavation nearby, and utility clearance.
- Excavation of the contaminated soil
- Transportation and disposal of the excavated material at an offsite disposal facility
- Backfill and restoration of excavated areas
- Implementation of ICs to restrict the land use.

A backhoe or excavator is generally used to perform the excavation. Excavated materials will be sampled for waste characterization for offsite disposal. The site will be backfilled with clean soil and vegetated. Sampling at bottom and side walls of the excavations will be conducted to confirm complete removal of the contaminated soil.

It is assumed for purposes of this FS the excavated soil will be characterized as non-hazardous waste based on historical data. Waste characterized as non-hazardous waste would be transported and disposed of at a RCRA Subtitle D Landfill. But if the excavated soil is hazardous, it will be transported and disposed of at a RCRA Subtitle C Landfill.

Alternative S-2 will meet the site RAOs by removal of the contamination offsite to prevent direct contact and prevent contaminants migrating to the groundwater and/or surface water. Since the material would be removed from the site, there would not be any post-remedial action maintenance or monitoring, except five year reviews, and the site would be available for assumed land uses.

5.4 ALTERNATIVE S-3: SOIL EXCAVATION AND ONSITE CONTAINMENT REPOSITORY

Alternative S-3 includes excavating the contaminated soil and consolidating and placing the excavated soil in a containment repository constructed onsite. A potential location of the containment repository can be in the mid-portion of the Wilcox Process Area, as showed in Figure 3-1, which is away from tributaries and drainage basins or creeks. The location of the containment repository will be determined during the remedial design and shall be in accordance with ODEQ solid waste rules and Oklahoma Administrative Code (OAC) 252 Chapter 515. The excavation of the contaminated soil in this alternative is the same as that in Alternative S-2. However, the excavated soil will be placed in an onsite containment repository, rather than being transported offsite for disposal. The containment repository will be constructed to meet the regulatory requirements for RCRA subtitle D landfill and OAC 252:515.

The main components of Alternative S-3 include:

- Same components from Alternative S-2 for soil excavation, backfill and restoration of the excavated areas.

- Site preparation of the containment repository area including removal of vegetation and setup of the boundaries of the repository based on containment repository design.

- Installation of bottom liner of the containment repository.

- Placement and compaction of the excavated soil in the containment repository.

- Installation of a low permeability cap.

- Implementation of ICs to restrict the land use to industrial and commercial in the containment repository area and prohibit any drilling and earth-moving activities at the repository area.

- Implementation of a groundwater program to monitor groundwater around the repository area in accordance with regulatory requirements.

A containment repository in general consists of, from bottom to the top:

- A bottom liner:
    - Compacted clay liner in 12-inch thickness with a hydraulic conductivity less than 1×10^{-7} centimeter per second (cm/s)
    - Geosynthetic clay liner
    - 60-milli-inch (mil) HDPE textured geomembrane
    - Composite drainage net
    - Protective cover.
- Excavated contaminated soil
- A cap:
    - A geosynthetic clay liner with a hydraulic conductivity less than 1×10^{-8} cm/s
    - A textured 60-mil low-density polyethylene geomembrane
    - A drainage layer constructed with composite drainage net
    - A protective soil cover at least 2.5 ft in thickness
    - A vegetation layer at least 6 inches in thickness.

A leachate collection system is assumed not necessary for the site soil under this alternative. Water in a containment repository may be generated from precipitation entering through the cap, and the initial moisture content of the soil itself. Physical, chemical, and biological processes of the soil compounds can also produce water and other compounds, but the water generated from these processes is small compared to precipitation and infiltration. Due to the impermeable cap of the containment repository, precipitation into the repository would be limited and reduced. Therefore the leachate generated from the repository is likely low. However, if this alternative is selected, design of the repository will need to include a water balance analysis to determine if a leachate collection system is required.

This alternative will address the RAOs by containing the contaminated material in the repository to prevent the direct exposure to the environment and leaching to the groundwater. However, the contaminated soil would remain at the site, thus ICs would be required to restrict the future land use and earth moving activities, which could potentially damage the repository. Groundwater will be monitored to confirm that the bottom liner prevents the contaminants in the repository from leaching to the groundwater.

5.5 ALTERNATIVE S-4: SOIL EXCAVATION AND ONSITE CONSOLIDATION AND CAPPING

Alternative S-4 includes excavating the contaminated soil and consolidating and capping it at the site. A potential location of the consolidation and capping can be the same as the location of the containment repository under Alternative S-3, as showed in Figure 3-1. The consolidation and capping location shall be selected in accordance with ODEQ solid waste rules and OAC 252 Chapter 515. The excavation of the contaminated soil in this alternative is the same as that in Alternative S-2. However, the excavated soil will be placed in a location and capped, rather than being transported offsite for disposal.

The main components of Alternative S-4 include:

- Same components from Alternative S-2 for soil excavation, backfill and restoration of the excavated areas.
- Site preparation of the consolidation and capping area including removal of vegetation, and setup of work zones, staging areas, and the boundaries of the consolidation and capping.
- Placement and compaction of the excavated soil in the consolidation area.
- Installation of a low permeability cap, which would be the same as the cap under Alternative S-3.
- Implementation of ICs to restrict the land use to industrial and commercial in the capping area and prohibit any drilling and earth-moving activities at the capping area.

- Implementation of a groundwater program to monitor groundwater around the cap in accordance with regulatory requirements.

This alternative will address the RAOs by capping the contaminated soil to prevent the direct exposure to the environment, and minimize infiltration, therefore reducing leaching of the contaminants to the groundwater. However, the contaminated soil would remain at the site, thus ICs would be required to restrict the future land use and earth moving activities. Groundwater will be monitored to confirm that the capped contaminants are prevented from leaching to the groundwater.

6 EVALUATION OF REMEDIAL ALTERNATIVES

This section evaluates the remedial alternatives developed in the previous section following the EPA's RI/FS guidance (EPA 1988). The alternatives were evaluated against the seven of the nine criteria required in the NCP. Alternatives are compared, and key tradeoffs among them are identified to determine the most appropriate remedial actions for the site. The approach is designed to provide decision-makers with sufficient information to adequately compare the alternatives and provide the basis for selecting an appropriate site remedy pursuant to CERCLA requirements.

6.1 EVALUATION CRITERIA

The alternatives are evaluated in this section based on the nine criteria required by 40 CFR Section 300.430(e). The nine criteria used to evaluate each alternative are listed below:

Threshold Criteria

- Overall protection of human health and the environment
- Compliance with ARARs

Balancing Criteria

- Long-term effectiveness and permanence
- Reduction in toxicity, mobility, or volume through treatment (TMV)
- Short-term effectiveness
- Implementability
- Cost

Modifying Criteria

- State acceptance
- Community acceptance.

The evaluation criteria are divided into three groups: threshold, balancing, and modifying criteria. The first two criteria as threshold criteria must be met by all alternatives in order to be eligible for selection as a remedial action. If ARARs are not met, six circumstances may be considered as listed in the NCP (see 40 CFR 300.430 (f)(1)(ii)(C)(1 to 6)), and a waiver may be obtained before the alternative being selected as a remedy. The next five criteria as balancing criteria are the primary criteria upon which the detailed analysis is based. Unlike the threshold criteria, the five balancing criteria weigh the tradeoffs between alternatives. A low ranking for one balancing criterion can be offset by a higher ranking on another balancing criteria. The last two criteria as modifying criteria are deferred until the public comment process and following receipt of feedback from the state and community. The nine criteria are described in the following subsections.

6.1.1 Threshold Criteria

To be eligible for selection, an alternative must meet the two threshold criterion or, in the case of ARARs, must justify why a waiver is appropriate.

- **Overall Protection of Human Health and the Environment.** A remedy is protective if it adequately eliminates, reduces, or controls all current and potential risks posed by the site through exposure pathways. Evaluation of protectiveness focuses on the reduction or elimination of site risks by the proposed remedial alternative.

- **Compliance with ARARs.** This criterion is used to evaluate whether each alternative will meet all of the federal and state ARARs or whether there is justification for waiving one or more ARARs. Table 3-1 identifies and presents ARARs for the site.

6.1.2 Balancing Criteria

There are five balancing criteria, described below.

- **Long-Term Effectiveness and Permanence.** This criterion is used to assess the residual risks at the site after RAOs have been met. The primary focus of this criterion is the extent and effectiveness of controls used to manage the risk posed by treatment residuals or untreated materials remaining at the site. The following factors will be considered under this criterion:

    - Adequacy and reliability of remedial controls to mitigate the remaining risks after the remedial activities

    - Magnitude of the residual risks after remedial activities.

- **Reduction of TMV through Treatment.** This evaluation criterion addresses the CERCLA statutory preference for treatment options that permanently and significantly reduce the TMV of the contaminants. The following factors will be considered under this criterion:

    - The amount of hazardous materials that will be destroyed or treated
    - The degree of reduction in TMV measured as a percentage of reduction
    - The degree to which the treatment will be irreversible
    - The type and quantity of treatment residuals that will remain following treatment.

- **Short-Term Effectiveness.** This evaluation criterion addresses the effects of the alternative during the construction and implementation phase until the RAOs are met. Under this criterion, alternatives are evaluated for their effects on human health and the environment during implementation of the remedial action. The following factors will be considered:

- Exposure of the community during implementation
- Exposure of workers during construction
- Environmental impacts resulted from implementation and construction
- Time to achieve RAOs
- Sustainability.

- **Implementability.** This criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials that may be required during its implementation. The following factors were considered:

  - Ability and difficulties to construct the technology
  - Ability to monitor effectiveness of the remedy
  - Availability of equipment and specialists
  - Availability of offsite treatment and disposal capacity and services
  - Ability to obtain approvals from regulatory agencies.

- **Cost.** Cost encompasses capital, operation and maintenance costs incurred over the life of the project. As stated in the EPA guidance (EPA 2000), cost estimates in the FS are expected to provide an accuracy of minus 30 percent to plus 50 percent (-30 percent to +50 percent). The estimated costs are designed to be used only for evaluating and comparing alternative technologies and not for setting budgets.

  The Remedial Action Cost Engineering and Requirements® (RACER) software, Version 11.4, was used to develop order-of-magnitude costs for this FS. RACER® is a parametric and integrated cost estimating program that was developed specifically for estimating costs associated with environmental investigation and remediation projects. It can be used at early order-of-magnitude stages of cost estimating. RACER® has been used by Department of Defense, Department of Energy, contractors, engineering consultants, state regulatory agencies and private sectors.

6.1.3 Modifying Criteria - State and Community Acceptance

State and community acceptance are the two modifying criteria. These two criteria evaluate the issues and concerns of the state and community regarding each alternative. These criteria cannot be evaluated until the state and community have reviewed and commented on the alternatives presented in the FS Report.

6.2 ALTERNATIVE EVALUATION

Evaluation of alternatives consists of the following two components:

- Evaluation of each alternative against seven of the nine evaluation criteria.

- Comparative evaluation of alternatives relative to one another to identify key tradeoffs.

Table 6-1 presents the detailed evaluation of soil alternatives individually and following subsection presents comparative evaluation of the alternatives. The detailed evaluation confirms if alternatives achieve the threshold criteria, presents significant aspects and differentiators of the alternatives, and identifies uncertainties associated with the evaluation.

6.3 COMPARATIVE ANALYSIS

This section presents the comparison among the alternatives based on the detailed evaluation of each alternative. The comparison potentially identifies the most favorable alternative on each evaluation criterion. Table 6-2 provides a summary of comparative analysis for the soil alternatives.

6.3.1 Overall Protection of Human Health and Environment

All alternatives, except S-1 NFA, provide overall protection of human health and environment by removing the contaminants and containing the excavated soil either offsite or onsite, or capping the soil onsite to eliminate or reduce the site risks. Alternatives S-2, S-3 and S-4 include ICs to restrict land use to industrial and commercial only in the Wilcox Process Area. Alternatives S-3 and S-4 will also consist of additional ICs to protect the containment repository and cap, respectively.

Alternative S-2 ranks the most satisfactory among the three alternatives regarding protection of human health and environment because the contaminated materials would be removed permanently and disposed offsite in an approved landfill with limited human health and environment risk. Under Alternatives S-3 and S-4 however, more protection measures (i.e., ICs) would be used to maintain protection at the site.

6.3.2 Compliance with ARARs

Table 3-1 presents a compilation of the federal, state, and local ARARs identified for the site. Compliance with ARARs is not applicable to S-1, NFS. All other alternatives are anticipated to comply with ARARs.

6.3.3 Long-Term Effectiveness and Permanence

All alternatives, with the exception of Alternative S-1, provide long-term effectiveness and permanence with different extents. Alternative S-2 would provide the best long-term effectiveness and permanence because all contaminated materials are removed and disposed offsite. Alternatives S-3 and S-4 would leave the contaminated materials onsite and require long-term monitoring and maintenance to protect the contaminated materials, eliminate direct exposure to all receptors, and prevent leaching into the groundwater.

6.3.4 Reduction of TMV through Treatment

All alternatives except Alternative S-1 reduce the mobility of the contaminated materials, and none of the alternative, however would reduce the toxicity and volume of the contaminated soil. Therefore, Alternatives S-2, S-3, and S-4 rank the same regarding reduction of TMV.

6.3.5 Short-Term Effectiveness

All alternatives, except Alternative S-1, pose short-term impacts during implementation of the alternatives on workers, communities, and the environment; however, the impacts are low. Proper personal protective equipment and best practice management will be used to alleviate the impacts. Alternative S-3 would require a longest time to implement than Alternatives S-2 and S-4, because under this alternative a containment repository would be constructed to contain the excavated materials. However, Alternative S-2 would present a greater risk to the community with the offsite transportation of wastes. .

6.3.6 Implementability

All alternatives except S-1 involve mature technologies and typical construction methods and equipment. Thus, they are readily implementable. However, Alternatives S-3 and S-4 involves more processes and technologies than Alternative S-2. Constructing a containment repository or a cap under respective Alternatives S-3 and S-4 would require more materials compared to Alternative S-2, and would involve a quality control and quality assurance program to ensure the liners or cap are constructed in accordance with the design. Therefore, Alternative S-2 ranks the most satisfactory regarding implementability, followed by Alternative S-4, then Alternative S-3.

6.3.7 Cost

Table 6-1 presents the cost of the alternatives for soil. Appendix B provides the detailed cost estimates. Overall Alternative S-3 is highest in 30-year net present value among the alternatives.

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Tables

Table 3-1. Potentially Applicable or Relevant and Appropriate Requirements

ARARs/TBCs	Citation or Reference	Requirements	Applicability
Chemical-Specific ARARs			
Designation of Hazardous Substances, Determination of Reportable Quantities	40 CFR 302.4 – 302.5	This section provides tables on the following substances: a). Listed hazardous substances. The elements, compounds, and hazardous wastes appearing in Table 302.4 are designated as hazardous substances under Section 102(a) of CERCLA. b). Unlisted hazardous substances. A solid waste, as defined in 40 CFR 261.2, which is not excluded from regulation as a hazardous waste under 40 CFR 261.4(b), is a hazardous substance under Section 101(14) of CERCLA if it exhibits any of the characteristics identified in 40 CFR 261.20 through 261.24.	Applicable because hazardous substances might be in the contaminated soil. Waste encountered during the remediation of the contaminated soil will be characterized to determine whether it is hazardous or nonhazardous.
Identification and Listing of Hazardous Waste	40 CFR 261.10; 261.20 - 24	Identifies those waste subject to regulation as hazardous wastes.	The criteria and limitations used to identify wastes as being hazardous or nonhazardous are applicable to all wastes and are relevant and appropriate to all alternatives at the site.
Oklahoma Air Pollution Control Rules	OAC 252:100-3-4; 100-24-4, 100-24-6; 100-29; 100-43-2 to 100-43-5	Establishes controls for air pollutants; establishes visible emissions limit, fugitive dust controls, and testing and monitoring requirements for air quality.	Applicable to discharge of fugitive dust during remedial actions, i.e., excavation, and placement of contaminated soil in the containment repository.
Airborne Contamination Monitoring	American Conference of Governmental Industrial Hygienists – Threshold Limit Values (TLV)	Based on the development of a time-weighted average exposure to an airborne contaminant over an 8-hour workday or a 40-hour workweek, TLVs identify levels of airborne contaminants at which health risks may be associated.	Applicable during implementation of alternatives.
Airborne Contamination Monitoring	American Conference of Governmental Industrial Hygienists – Estimated Limit Values (ELV)	ELVs provide some indication of airborne contaminant levels at which adverse health effects could occur.	Applicable during implementation of alternatives.

ARARs/TBCs	Citation or Reference	Requirements	Applicability
OSHA Worker Protection	29 CFR 1910 subparts D, E, F, G, and I; 1910.145-147, 1926.21, 1926.24, 1926.28, 1926.52, 1926.62; and 1926 subpart E;	Establishes requirements for occupational health and safety applicable to workers engaged in hazardous waste site or CERCLA response actions	Applicable during implementation of alternatives.
Location-Specific ARARs			
Migratory Bird Treaty Act	16 United States Code (USC) 703	Protects almost all species of native birds in the United States from unregulated taking.	Applicable if work is taking place in a migratory flyway.
Permits and Enforcement	CERCLA 121 (e)	This section of CERCLA states that no "federal, state, or local permit" shall be required for any portion of a CERCLA remedial action that is conducted on the site of the facility being remediated. This includes exemption from the Resource Conservation and Recovery Act (RCRA) permitting process. Note that the substantive requirements of the regulations must still be met (e.g., construction stormwater must be managed using best management practices [BMPs]).	Applicable to the remedial action at the site.
The Native American Graves Protection And Repatriation Act	25 USC Section 3002 and its regulations Title 43 CFR Part 10.4	Protects Native American graves from desecration through the removal and trafficking of human remains and cultural items including funerary and sacred objects.	Substantive requirements applicable if Native American burials or cultural items are identified within area to be disturbed.
National Historic Preservation Act	16 USC 470 et seq; 36 CFR Part 800.4 – 8; 800.10	Provides for the protection of sites with historic places and structures	Substantive requirements applicable if eligible resources are identified within area to be disturbed.
Archeological Resources Protection Act of 1979	16 USC Sections 470cc (b), (c), ; 43 CFR Part 7.4, and 7.7	Prohibits removal of or damage to archaeological resources unless by permit or exception	Substantive requirements applicable if eligible resources are identified within area to be disturbed.

ARARs/TBCs	Citation or Reference	Requirements	Applicability
American Indian Religious Freedom Act	42 USC Section 1996 et seq.	Protects religious, ceremonial, and burial sites, and the free practice of religions by Native American groups.	Substantive requirements applicable if Native American sacred sites are identified within area to be disturbed.
ACTION-SPECIFIC ARARs			
RCRA	40 CFR. Part 262 Subpart B, & Part 263 Subparts B and C	Establishes responsibilities for transporters of hazardous waste in handling, transportation, and management of the waste. Sets requirements for manifesting, recordkeeping, packing, labeling, and emergency response action in case of a spill.	Applicable depending on waste classification and if it is transported offsite for disposal.
RCRA Land Disposal	40 CFR Part 268.32, 34-37, and subpart D,	Land Disposal Restrictions (LDRs): Establishes restrictions on land disposal unless treatment standards are met or a "no migration exemption" is granted. LDRs establish prohibitions, treatment standards, and storage limitations before disposal for certain wastes as set forth in Subparts C and D. Treatment standards are expressed either as concentration based performance standards or as specific treatment methods. Wastes must be treated according to the appropriate standard before wastes or the treatment residuals of wastes may be disposed in or on the land. The Universal Treatment Standards establish a concentration limit for 300 regulated constituents in soil regardless of waste type.	Applicable for disposal of hazardous wastes, if the site soil is characterized as such.
Transportation	49 CFR. Part 171 Subparts A & B	Hazardous materials that may be transported off site cannot be transported in interstate and intrastate commerce, except in accordance with the requirements of 49 CFR Part 171, Subpart C.	Applicable for any offsite transportation of hazardous waste will comply with these regulations, which contain packaging, placarding, labeling, and other shipping requirements.
Criteria for Classification of Solid Waste Disposal Facility and Practices	40 CFR 257.3	Sets standards for land disposal facilities for nonhazardous waste.	Applicable to transport and disposal of any nonhazardous waste offsite.

ARARs/TBCs	Citation or Reference	Requirements	Applicability
Hazardous Waste Management; Standards Applicable to Generators of Hazardous Waste; and Standards Applicable to Transporters of Hazardous Waste	OAC 252:205 – Oklahoma Hazardous Waste Management Rules Sections 5-5, 9-3 & 9-4	Regulates the generation, transport, storage, treatment, and disposal of hazardous wastes generated in the course of a remedial action. Regulates the construction, design, monitoring, operation, and closure of hazardous waste facilities.	Requirements under these regulations may be relevant and appropriate to transportation and disposal of wastes.
Solid Waste Management	OAC 252:515-5, 515-11 – 13, 515-31	Implements the Oklahoma Solid Waste Management Act (OSWMA), which provides rules for the transportation, handling, storage, and/or disposal of solid waste regulated by the OSWMA.	The requirements are applicable to the transportation, handling, storage, and/or disposal of any solid wastes generated during remedial action.
Well Driller and Pump Installer Licensing	OAC 785:35	Establishes requirements for well drilling and plugging.	Potentially applicable if installation or plugging and abandonment of groundwater monitoring wells or boreholes takes place.
TBCs			
Floodplain Management	Executive Order 11988	Establishes federal policy and guidance for activities completed in floodplains	To be considered (TBC) since portions of the site are within a 100-year floodplain.
Protection of Wetlands	Executive Order No. 11990	Mandates that Federal agencies and potentially responsible parties avoid, to the extent possible, the adverse impacts associated with the destruction or loss of wetlands and avoid support of new construction in wetlands if a practicable alternative exists.	TBC during remedial actions since portions of the site are within or near wetlands.
Endangered Species Act of 1973	16 USC 1533-; 50 CFR 17.11-12; 17.51-52; 17.61-62; and 17.71-72	Requires remedial agency to consult with Fish and Wildlife Service if action may affect endangered species or critical habitat. Requires action to conserve endangered species within critical habitats upon which endangered species depend, includes consultation with Department of Interior.	No documentation is found to show endangered species are present at the site, however, it is TBC to confirm that during the soil remediation.

ARARs/TBCs	Citation or Reference	Requirements	Applicability
Notes: ARAR = Applicable Relevant and Appropriate Requirement BMP = best management practice CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act CFR = Code of Federal Regulations ELV = Estimated Limit Values LDR = Land Disposal Restrictions OAC = Oklahoma Administrative Cod OSWMA = Oklahoma Solid Waste Management Act RCRA = Resource Conservation and Recovery Act TBC = To be considered TLV = Threshold Limit Values USC = United States Code			

Table 4-1. Technology Screening for Soil

General Response Action	Remedial Technology Type	Process Option	Description	Effectiveness	Implementability	Cost	Potential for Retain for Further Evaluation
No Further Action	None	None	No further action to address contaminated soil.	Will not address the remedial objectives.	None	None	Yes as baseline for evaluation process
Institutional Controls	Access and Use Restrictions	Land Use Controls	Land use restriction (i.e., deed notice or restrictive covenant) is issued fo properties located in the contaminated areas.	Will minimize direct exposure to the contaminants; therefore it will address remedial objectives partially. The current and future land use of the site is residential; and industrial and commercial i the south of the Wilcox Process Area.	Implementable	Low	**Yes**
Containment	Consolidation and Capping	Clay Cap, Synthetic Membrane, or Chemical Sealant or Stabilizers	A cap is installed to cover the contaminated area to prevent direct exposure to the contamination. Different materials can be used for the cap and typical materials include clay, synthetic membranes, and chemical sealants or stabilizers. Contaminated soil can be consolidated i one area and capped.	Will prevent direct contact and exposure to the contaminated soil although it does not remove the source of the contamination. It will address the relevant remedial objectives.	Implementable with commercially available equipment; potential worker and community exposure to dust; institutional controls will be required t protect the cap.	Medium	**Yes**
Removal	Excavation and Disposal	Excavation and Onsite Disposal	Contaminated soil is excavated and placed in a containment repository, which may consist of a bottom liner and a cap. Bottom liner may consist of, from bottom to top a impermeable liner, leachate collection layer, a protection layer overlain by excavated contaminated soil. A cap may consist of an impermeable layer, an infiltration collection layer, and soil cover and vegetation.	Will prevent direct contact and exposure to the contaminated soil by containing the contaminated materials in a repository. It will address the relevant remedial objectives.	Implementable with commercially available equipment. Potential worker and community exposure to dust during the construction, therefore dust controls will be required. Institutional controls are required to control the future land use and protect the integrity of the containment repository.	Medium	**Yes**
		Excavation and Offsite Disposal	Contaminated soil are excavated and transported to a permitted offsite facility for disposal.	Will remove the contaminated soil from the site. It will address the relevant remedial objectives.	Implementable. Potential worker and community exposure to dust durin the construction and transportation for offsite disposal, therefore dust controls will be required.	Medium	**Yes**
Treatment	In situ Physical, Chemical Treatment	Stabilization/Solidification	Reagents are mixed with soil to trap, treat, or immobilize contaminants. Treatment would stabilize and prevent contaminants leaching to the groundwater. Reagents may include Portland cement, bentonite, fly ash, organoclay, and activated carbon.	Will stabilize and reduce contaminants' migration, treated soil wi remain onsite; administrative controls and land use restrictions will be required.	Implementable with commercially available equipment; treatability studies are required; and potential worker exposure to contaminants is present during mixing.	High. The contaminated soil is likely not hazardous, therefore the treatment is less cost effective compared to containment technologies.	No, due to high cost and lower benefit of treating the soil compared to containment technologies.
	Biological	Landfarming	Landfarming is used for the biological treatment of contaminated soil. It consists of spreading excavated contaminated soil either directly on the ground or on a membrane with an upper protective layer to prevent contaminants from migrating to the soil underneath and to the groundwater. Mixing or tilling of the contaminated soil is normally required to blend nutrients/amendments, and distribute moisture to promote biodegradation of the contaminants. Periodical watering is also required to provide optimal condition for microbial activities.	Landfarming is typically applicable to nonvolatile and semi-volatile compounds. Biodegradation of PAHs becomes more difficult as the number of aromatic rings increase. Therefore landfarming typically is not considered to be effective for treating PAHs that contain more than four rings, i.e., benzo(a)pyrene. It is not certain if landfarming will be effective for treating lead in soi with data currently available.	Implementable, however it may take a long period of time depending on biodegradation process in the soil.	Low	No due to ineffectiveness with inorganics
		Phytoremediation	Phytoremediation is a process that uses plants to remove, transfer, stabilize, and destroy contaminants in soil and sediment. The mechanism of phytoremediation include enhanced rhizosphere biodegradation, phyto-extraction (also called phyto-accumulation), phyto-degradation, and phyt stabilization.	Under controlled experimental settings, a variety of plants have been shown to remediate both lead and benzo(a)pyrene in surfac soil. Treatability and pilot studies would be required to determin the effectiveness of phytoremediation at the site.	Technology is potentially implementable with pilot study. However, climate, site soil type, and / or lithology characteristics may not be conducive to needed plant/tree species. Limited species are effective with metals. It may also require a long period of time compared to other technologies depending on season and temperature.	Medium	No due to the concern on implementability
	Ex situ Physical, Chemical Treatment	Excavation and Chemical Oxidation	Oxidizing agents (Fenton's reagent, permanganate, and ozone) are added into the excavated soil to promote abiotic destruction of contaminants.	Chemical oxidation will make lead and other metals become soluble, potentially causing mobilization of metals to groundwater.	Implementable	High. Can be cost prohibitive if the soil contains high organic matter.	No, due to the concern for mobilizing lead to groundwater and high cost.
		Excavation and Soil Mixing and Stabilization/Solidification	Reagents are mixed with excavated soil by a mechanical mixing device t trap, treat, or immobilize contaminants. Treated soil may be placed onsite for future applicable land use. Reagents may include Portland cement, bentonite, fly ash, organoclay, and activated carbon.	Will stabilize and reduce contaminants' migration, treated soil wi remain onsite; administrative controls and land use restrictions will be required.	Implementable with commercially available equipment; treatability studies are required; and potential worker exposure to contaminants is present during excavation and mixing.	High. The contaminated soil is likely not hazardous, therefore the treatment is less cost effective compared to containment technologies.	No, due to high cost and lower benefit of treating the soil compared to containment technologies.
		Excavation and Soil Washing	Contaminants in soil are desorbed by using a solution of leaching agent, surfactant, pH-adjustment, or chelating agent to help remove the contaminants and fine materials on which the contaminants absorbed.	Will address the remedial objectives by removing the contaminants from the soil .	Complex process and produce a large quantity of process water that requires treatment. Acid reagent may be used to remove lead from soil, which increase the health and safety concern during the implementation.	High	No due to the concern on implementability
		Excavation and Thermal Treatment	Heat is applied to the excavated soil to increase the volatility of the contaminants. An off-gas treatment will be used to treat the volatilized contaminants. *Ex situ* thermal treatment technologies include hot gas decontamination, incineration, thermal desorption, and vitrification, whic use a high temperature to immobilize contaminants and produce non-toxic vitreous stabilized products.	Will destroy or remove and recover the contaminants, so it will address the remedial objectives.	Not readily implementable, treatability studies required; significant materials handling; specialized equipment and operators; extended construction/ treatment period (6-7 months); and viscous nature may require pre-treatment. If treated soil is placed onsite, beneficial use of the treated soil shall be studied for future land use, and institutional controls may be required.	High; not cost effective for the relatively low concentrations of the contaminants at the site.	No, due to complex implementation and cost

NOTE:
PAH = Polycyclic aromatic hydrocarbon

Table 5-1. Summary of Soil Alternatives

Alternative	Remedy Components			Remedial Action Objectives	
	Primary Technologies	**Disposal**	**Institutional Controls**	Prevent human exposure to the soils with concentrations of the COCs exceeding the PRGs.	Minimize and prevent migration of soil contaminants into the groundwater, surface water, and other site soils.
S-2	• Excavation • Backfill of excavation • Transportation of the soils offsite	Offsite RCRA Subtitle D Landfill	Land use restriction to industrial and commercial in the south of the Wilcox Process Area	Prevent human exposure to the soils and prevent migration of the soil contaminants by removing the contaminated soil and disposing in a permitted landfill.	
S-3	• Excavation • Backfill of excavation • Construction of an onsite containment repository and placement of the excavated soil in the repository	Onsite containment repository	• Land use restriction to industrial and commercial in the south of the Wilcox Process Area • IC to protect the integrity of the repository	Prevent human exposure to the soils and prevent migration of the soil contaminants by removing the contaminated soil and disposing in an onsite containment repository.	
S-4	• Excavation • Backfill of excavation • Consolidation and capping of the excavated soil onsite	Onsite capping	• Land use restriction to industrial and commercial in the south of the Wilcox Process Area • IC to protect the integrity of the cap	Prevent human exposure to the soils and minimize migration of the soil contaminants by consolidating and capping the contaminated soil onsite.	

Notes:

COC = Chemical of concern

IC = Institutional control
PRG = Preliminary remediation goal
RCRA = Resource Conservation and Recovery Act

TABLE 6-1
EVALUATION OF SOIL REMEDIAL ALTERNATIVES

Evaluation Criteria	S-1 - No Further Action	S-2 - Soil Excavation and Offsite Disposal	S-3 - Soil Excavation and Onsite Containment Repository	S-4 - Soil Excavation and Onsite Consolidation and Capping
1. Overall Protection of Human Health and the Environment				
How Alternative Provides Human Health and Environmental Protection	This alternative would not be protective of human health or the environment.	This alternative would protect human health and environment by removing the contaminated soil from the site and transporting and disposing it in an offsite permitted facility.	This alternative would protect human health and environment by containing the contaminated soil in a containment repository constructed onsite.	This alternative would protect human health and environment by consolidation and capping of the contaminated soil.
2. Compliance with ARARs				
Compliance with ARARs	No Action, so no rules apply.	Yes	Yes	Yes
3. Long Term Effectiveness and Permanence				
a. Magnitude of Residual Risk	Not applicable.	This alternative would permanently eliminate the risks and exposure to the soil contaminants from the site.	Once remediation is complete, because the contaminated soil still remains onsite, although contained, institutional controls and monitoring will be implemented to protect the remedy, therefore the residual risk would be low.	Similar to Alternative S-3, because the contaminated soil still remains onsite, although capped, institutional controls and monitoring will be implemented to protect the remedy, therefore the residual risk would be low. Groundwater monitoring will confirm the capped contaminated soil does not leach to the groundwater.
b. Adequacy and Reliability of Controls	Not applicable.	Removal of COC-impacted soil would be a permanent solution with long-term effectiveness.	Containment of COC-impacted soil with monitoring and institutional controls of the containment would be reliable to ensure long-term effectiveness of the remedy.	Consolidating and capping of COC-impacted soil with monitoring and institutional controls of the cap would be reliable to ensure long-term effectiveness of the remedy.
4. Reduction of Toxicity Mobility, and Volume Through Treatment				
a. Treatment Process Used and Materials Treated	Not applicable.	This alternative involves no treatment processes.	This alternative involves no treatment processes.	This alternative involves no treatment processes.
b. Amount of Hazardous Materials Destroyed or Treated	Not applicable.	The COCs will not be destroyed or treated.	The COCs will not be destroyed or treated.	The COCs will not be destroyed or treated.
c. Degree of Expected Reductions in Toxicity, Mobility, and Volume	Not applicable.	This alternative will reduce mobility of the COCs, but will not reduce the toxicity and volume of the impacted soil. The contaminated soil will just be removed from the site to an offsite disposal facility.	This alternative will reduce mobility of the COCs, but will not reduce the toxicity and volume of the impacted soil. Contaminated soil will be remaining onsite and will require five year reviews.	This alternative will reduce mobility of the COCs, but will not reduce the toxicity and volume of the impacted soil. Contaminated soil will be remaining onsite and will require five year reviews.
d. Degree to Which Treatment is irreversible	Not applicable.	No treatment process are used under this alternative.	No treatment process are used under this alternative.	No treatment process are used under this alternative.
e. Type of Residuals Remaining After Treatment	Not applicable.	No treatment process are used under this alternative.	COCs impacted soil will be remaining onsite after remedial action.	COCs impacted soil will be remaining onsite after remedial action.

Evaluation Criteria	S-1 - No Further Action	S-2 - Soil Excavation and Offsite Disposal	S-3 - Soil Excavation and Onsite Containment Repository	S-4 - Soil Excavation and Onsite Consolidation and Capping
5. Short Term Effectiveness				
a. Protection of Community During Remedial Actions	Not applicable.	There would be some short term risk to the community during excavation and transportation of contaminated soil, i.e., dust generation and trucks transporting waste from the site.	There would be some short term risk to the community during excavation and construction of the containment repository, i.e., dust generation and trucks transporting waste across the site.	There would be some short term risk to the community during excavation and construction of the cap, i.e., dust generation and trucks transporting waste across the site.
b. Protection of Workers During Remedial Actions	Not applicable.	Implementation of this alternative would pose a minimal risk to remedial workers or the environment as long as proper health and safety procedures are followed.	Implementation of this alternative would pose a minimal risk to remedial workers or the environment as long as proper health and safety procedures are followed.	Implementation of this alternative would pose a minimal risk to remedial workers or the environment as long as proper health and safety procedures are followed.
c. Environmental Impacts	Not applicable.	Engineering and administrative controls during excavation and removal activities would minimize the impacts to the environment. Stormwater pollution prevention procedures will be established to prevent the surface water from being impacted.	Engineering and administrative controls during excavation and repository construction would minimize the impacts to the environment. Stormwater pollution prevention procedures will be established to prevent the surface water from being impacted.	Engineering and administrative controls during excavation and cap construction would minimize the impacts to the environment. Stormwater pollution prevention procedures will be established to prevent the surface water from being impacted.
d. Time Until Remedial Action Objectives are Achieved	No RAOs achieved.	Excavation and offsite disposal can be achieved in a very short time frame, typically 6 months to a year.	Excavation and onsite containment repository can be achieved in a relatively short time frame, typically 6 months to a year.	Excavation and onsite capping can be achieved in a relatively short time frame, typically 6 months to a year.
6. Implementablility				
a. Ability to Construct and Operate the Technology	Not applicable.	Removal of soil is easily implemented with conventional construction equipment and no specialized work force is required.	Removal of soil and containment is easily implemented with conventional construction equipment and no specialized work force is required.	Removal of soil and capping is easily implemented with conventional construction equipment and no specialized work force is required.
b. Reliability of the Technology	Not applicable.	Excavation under this alternative is a widely proven technology that is reliable at removing COCs from the site.	The technologies used in this alternative, excavation and containment are reliable and quality control and quality assurance for containment construction shall be followed to protect the remedy reliability.	The technologies used in this alternative, excavation and capping are reliable and quality control and quality assurance for containment construction shall be followed to protect the remedy reliability.
c. Ease of Undertaking Additional Remedial actions, if Necessary	Not applicable.	It would be easy to undertake additional remedial actions if needed under this alternative, i.e., additional excavation.	It would be easy to undertake additional remedial actions if needed under this alternative, i.e., additional excavation , or additional treatment of the soil prior to containment, although repository design will require to be revised.	It would be easy to undertake additional remedial actions if needed under this alternative, i.e., additional excavation.
d. Ability to Monitor Effectiveness of Remedy	Not applicable.	It will be easy to collect confirmation samples to ensure complete removal of the contaminated soil.	It will be easy to monitor effectiveness of soil excavation and containment. Activities include confirmation sampling during the excavation and groundwater monitoring and periodical inspection of the repository.	It will be easy to monitor effectiveness of soil excavation and capping. Activities include confirmation sampling during the excavation and groundwater monitoring and periodical inspection of the cap.
e. Ability to Obtain Approvals from Other Agencies	Not applicable.	It would likely obtain approvals from other agencies.	It would likely obtain approvals from other agencies.	It would likely obtain approvals from other agencies.
f. Availability of Offsite Treatment, Storage, and Disposal Services and Capacity	Not applicable.	Offsite disposal is readily available for soil disposal.	Not required	Not required
g. Availability of Necessary Equipment and Specialists	Not applicable.	Equipment necessary to implement this remedy is readily available, no specialized equipment is required.	Equipment necessary to implement this remedy is readily available, no specialized equipment is required.	Equipment necessary to implement this remedy is readily available, no specialized equipment is required.
h. Availability of Prospective Technologies	Not applicable.	Technology readily available	Technologies readily available	Technologies readily available
7. Cost				
A. Total Present Value	**$0**	**$2,660,000**	**$5,070,000**	**$3,750,000**

Notes:

ARAR Applicable or Relevant and Appropriate Requirements
RAO Remedial Action Objectives
O&M Operation and Maintenance

TABLE 6-2
COMPARATIVE ANALYSIS OF SOIL REMEDIAL ALTERNATIVES

Criteria	Alternative S-1 No Further Action	Alternative S-2 Soil Excavation and Offsite Disposal	Alternative S-3 Soil Excavation and Onsite Containment Repository	Alternative S-4 Soil Excavation and Onsite Consolidation and Capping
Overall Protection of Human Health and the Environment	▼	▲	▲	▲
Compliance with ARARs	Not applicable	▲	▲	▲
Long-Term Effectiveness and Permanence	▼	▲	▼	▼
Reduction of Toxicity, Mobility, or Volume through Treatment	▼	▼	▼	▼
Short-Term Effectiveness	▲	▼	▼	▼
Implementability	▲	▲	▲	▲
Total Cost (30-Year Present Worth)	**$0**	**$2,660,000**	**$5,070,000**	**$3,750,000**

NOTES:

ARAR = Applicable or Relevant and Appropriate Requirements

▲ = In comparison with other alternatives, complies well with criteria.

▼ = In comparison with other alternatives, does not comply as well with criteria.

Figures

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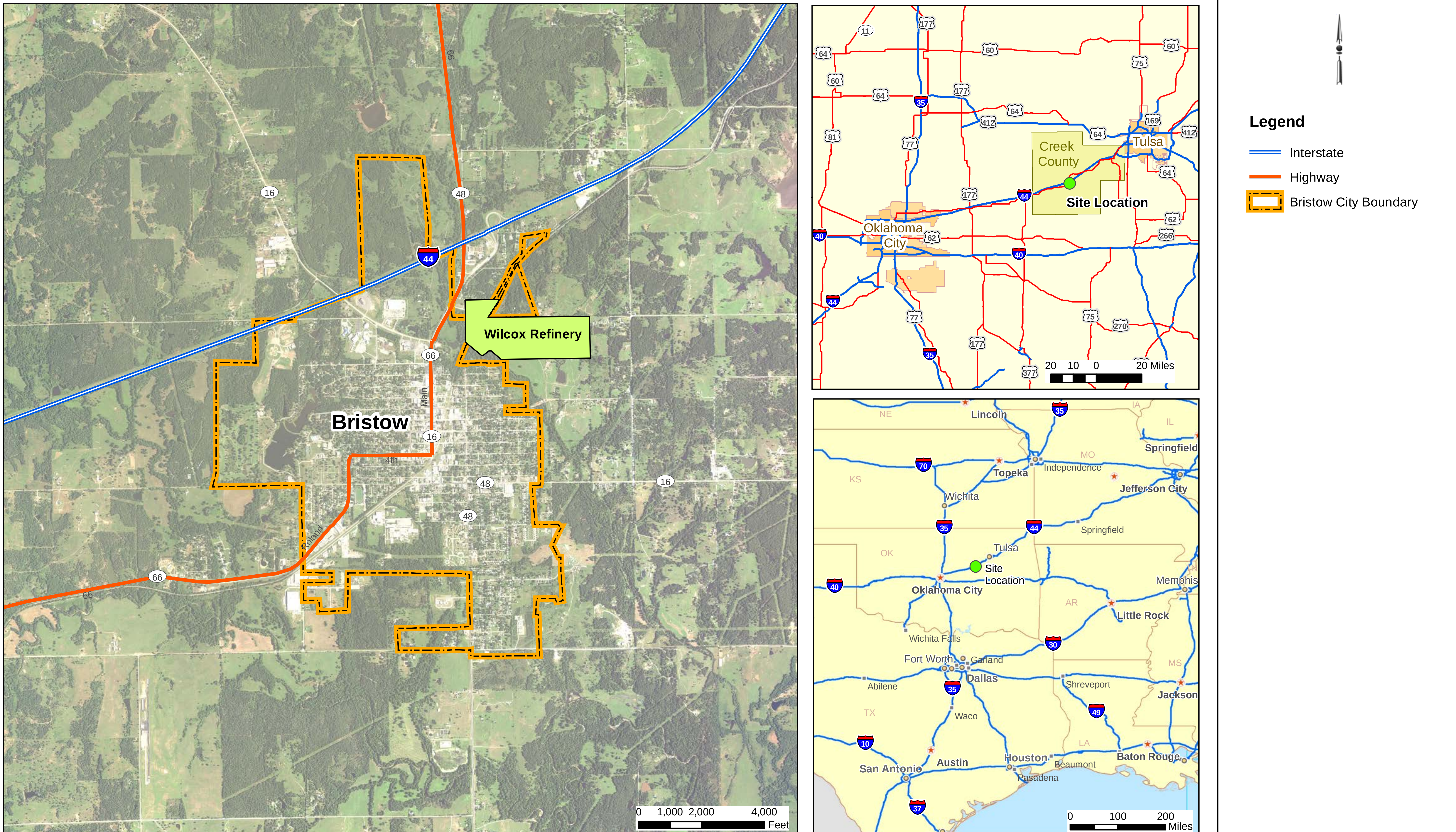


Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

Image Source: National Agriculture Imagery Program 2015

Figure 1-1
Site Location Map

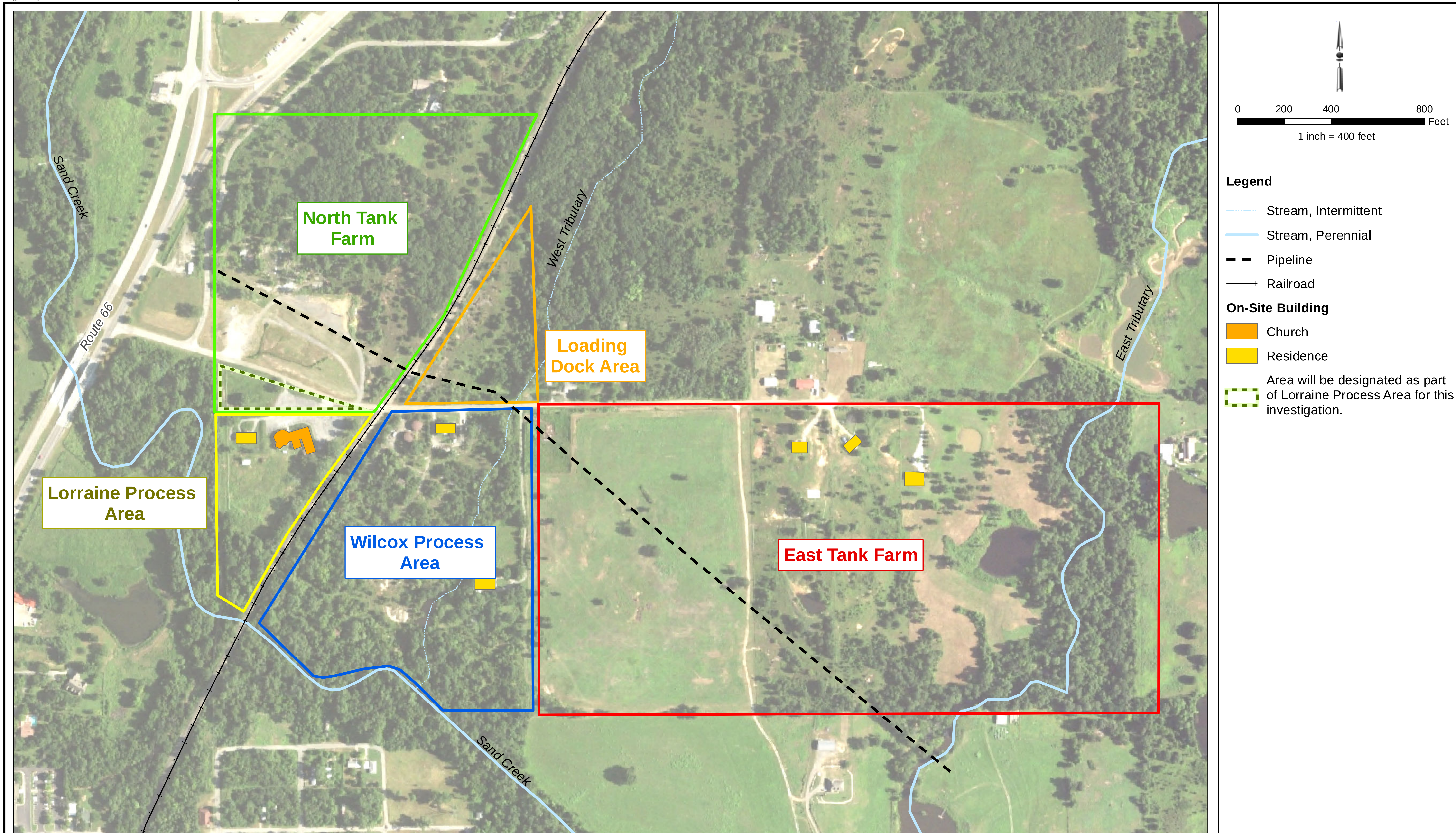
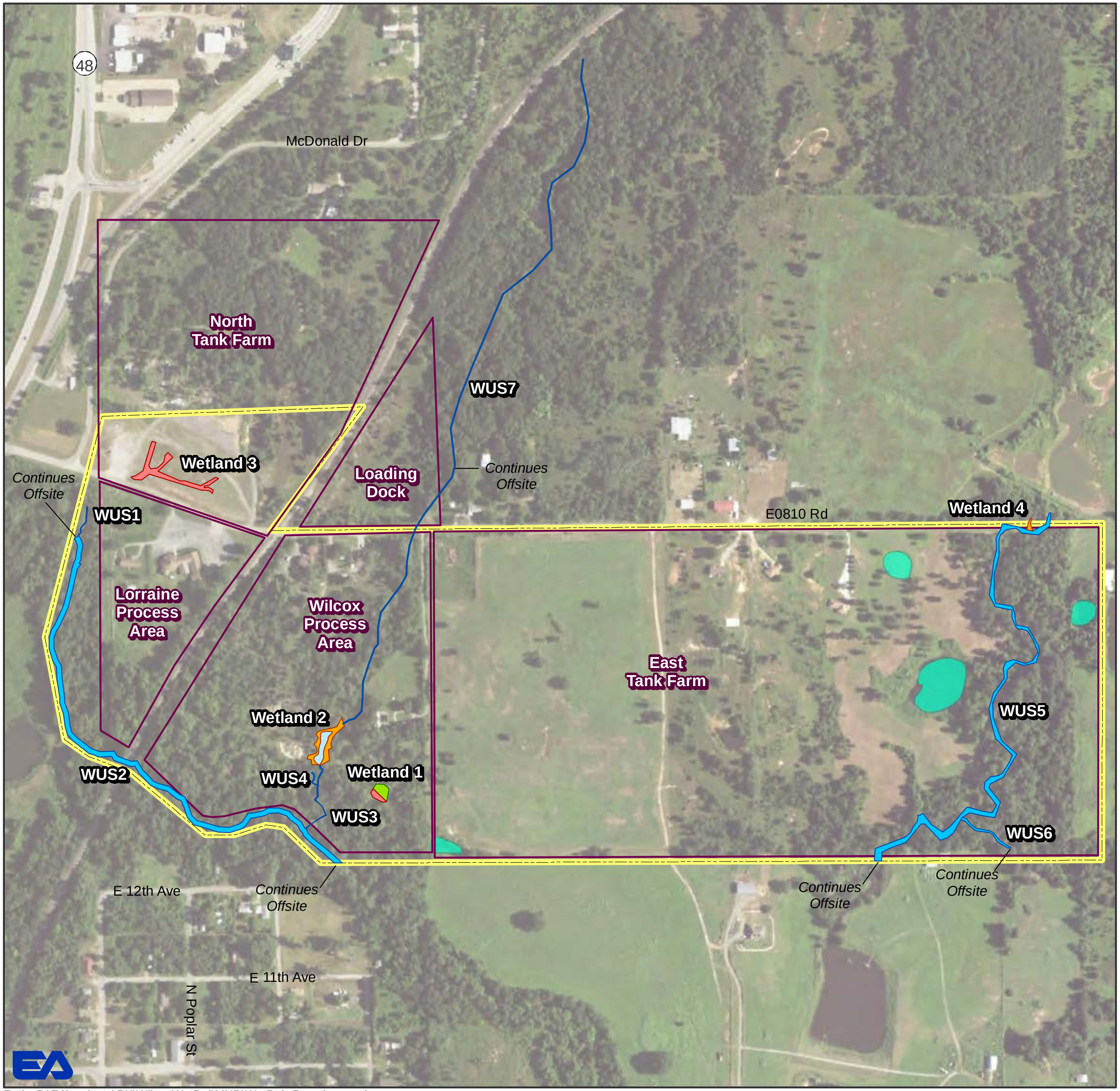


Image Source: National Agriculture Imagery Program 2015.

Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

FIGURE 2-1
SITE LAYOUT



Legend

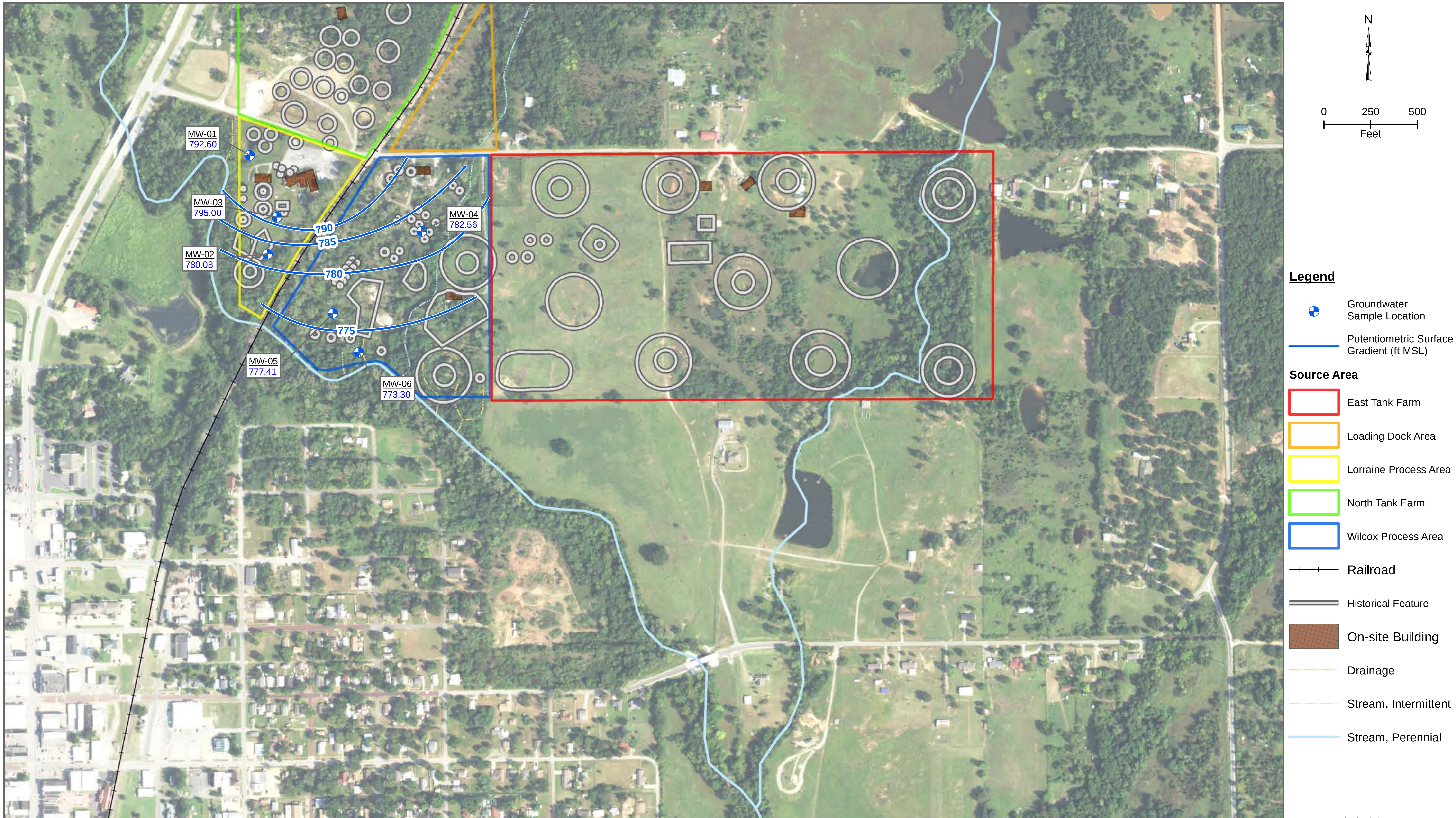
- Area of Review
- Farm Pond
- Source Area
- Emergent Wetland
- Forested Wetland
- Open Water
- Scrub-Shrub Wetland
- Waters of the U.S.

0 500 1,000
Feet

February, 2017
Data Sources: USDA, 2015

Wilcox Oil Company Superfund Site
Bristow, Oklahoma

Figure 2-2
Wetland Delineation Overview Map



Wilcox Oil Company
Bristow, Creek County, Oklahoma

Figure 2-3
Potentiometric Surface Map
December 2018

PRIMARY SOURCE	PRIMARY RELEASE MECHANISM	SECONDARY SOURCE	SECONDARY RELEASE MECHANISM	TERTIARY SOURCE	TERTIARY RELEASE MECHANISM	QUATERNARY SOURCE	EXPOSURE ROUTE	POTENTIAL RECEPTORS Current / Future: Commercial/ Industrial Worker	Recreational User/ Trespasser	Construction Worker	Resident
Source Areas (Refinery, Wood Treating, Pits, etc.)	Spills and Leaks	Surface Soil					Ingestion	C	C	C	C
							Dermal Contact	C	C	C	C
			Root Uptake	Homegrown Produce			Ingestion	I	I	I	C
				Cattle			Ingestion	I	I	I	C
			Wind Suspension	Outdoor Air (Particulates)			Inhalation	C	C	C	C
			Volatilization	Outdoor Air (VOCs)			Inhalation	I	I	I	I
			Overland Flow	Surface Water or Sediment			Ingestion	I	C	I	C
							Dermal Contact	I	C	I	C
					Wind Suspension	Outdoor Air (Particulates)	Inhalation	I	I	I	I
					Uptake/ Bioaccumulation	Fish (Fillet)	Ingestion	I	I	I	I
		Sediment					Ingestion	I	C	I	C
							Dermal Contact	I	C	I	C
					Desorption	Surface Water	Ingestion	I	C	I	C
							Dermal Contact	I	C	I	C
					Wind Suspension	Outdoor Air (Particulates)	Ingestion	I	I	I	I
		Surface Water					Ingestion	I	C	I	C
							Dermal Contact	I	C	I	C
			Sorption	Sediment			Ingestion	I	C	I	C
							Dermal Contact	I	C	I	C
					Wind Suspension	Outdoor Air (Particulates)	Inhalation	I	I	I	I
		Subsurface Soil					Ingestion	I	I	C	C
							Dermal Contact	I	I	C	C
			Wind Suspension	Outdoor Air (Particulates)			Inhalation	I	I	C	C
			Volatilization	Outdoor Air (VOCs)			Inhalation	C	I	C	C
				Indoor Air (VOCs)			Inhalation	C	I	I	C
			Infiltration and Percolation	Ground Water			Ingestion	C	I	C	C
							Dermal Contact	C	I	C	C
					Volatilization (Construction)	Construction Trench Air (VOCs)	Inhalation	I	I	C	I
					Volatilization (Domestic Use)	Indoor Air (VOCs)	Inhalation	C	I	I	C
					Volatilization (Vapor Intrusion)	Indoor Air (VOCs)	Inhalation	C	I	I	C

EXPLANATION

I	Incomplete or negligible exposure pathway
C	Potentially complete exposure pathway
VOC	Volatile organic compound

FIGURE 2-4 HUMAN HEALTH CONCEPTUAL SITE MODEL

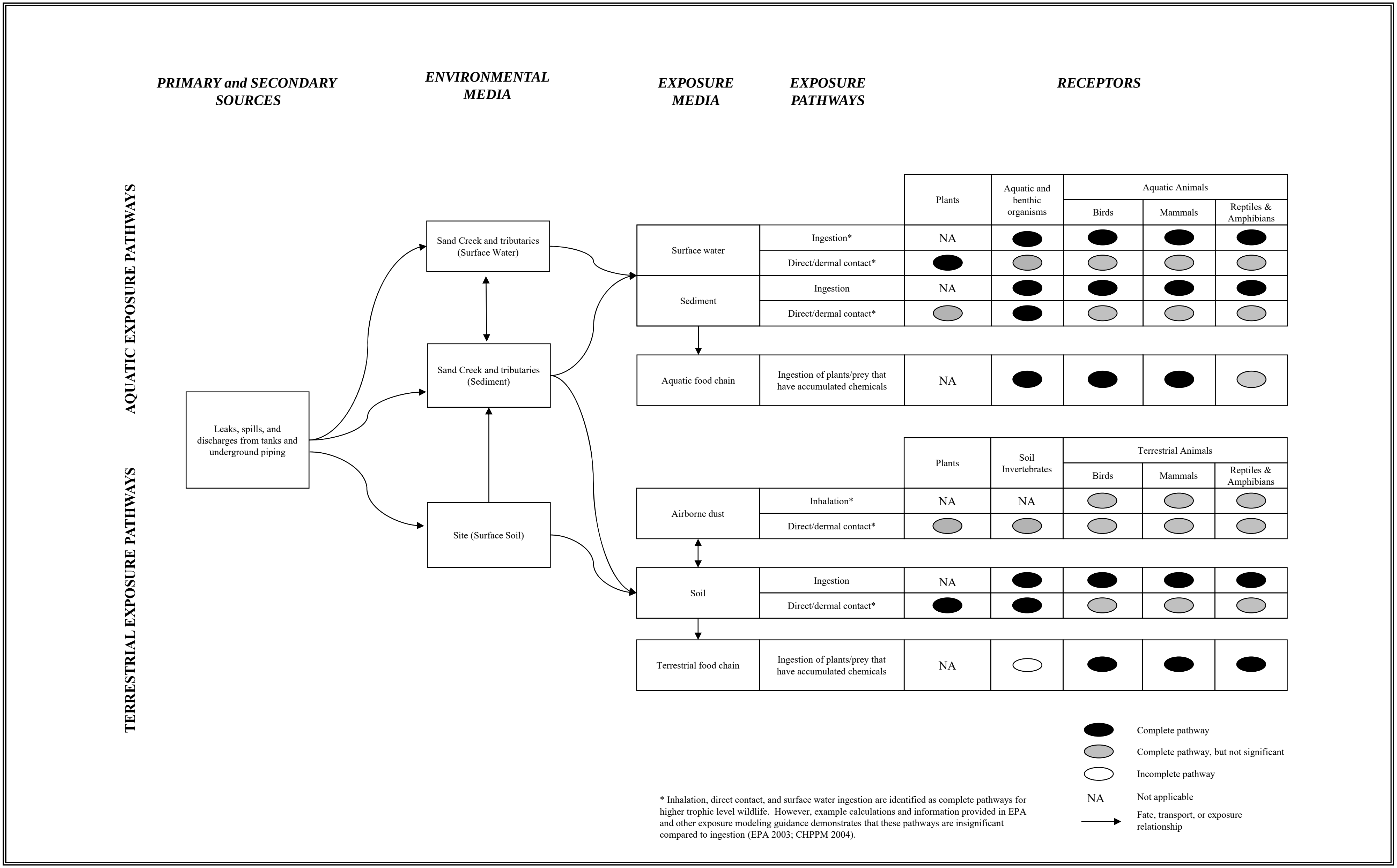
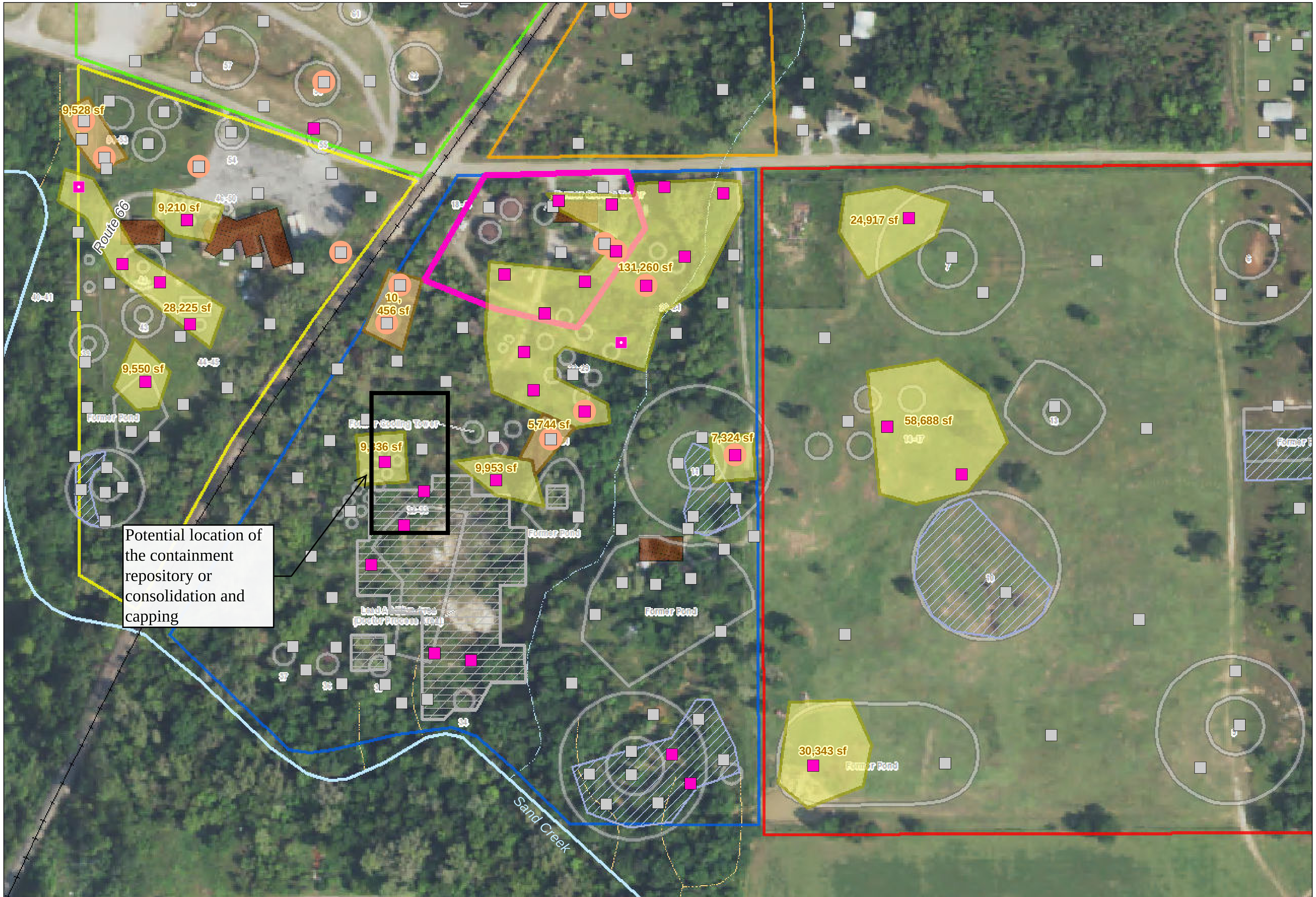


FIGURE 2-5 ECOLOGICAL CONCEPTUAL SITE MODEL



0 100 200 400 Feet

1 inch = 200 feet

Legend

- 0-2 ft bgs exceeding lead PRG
- 2- 6 ft bgs exeeding lead PRG
- Not exceeding lead PRG
- Exceeding benzo(a)pyrene PRG

Feasibility Study Remediation Areas

- Lead and B(a)P
- B(a)P only
- Wilcox Process Area Residential Area
- Estimated Waste Excavation Area Covered Under the Source Area Removal ROD
- Proposed Lead Excavation Area
- Railroad
- East Tank Farm
- Loading Dock Area
- Lorraine Process Area
- North Tank Farm
- Wilcox Process Area
- Historical Feature
- On-site Building
- Drainage
- Stream, Intermittent
- Stream, Perennial

Notes:
PRG -Preliminary Remediation Goal
B(a)P - Benzo(a) pyrene
mg/kg - milligram per kilogram
ft bgs - feet below ground surface

Image Source: National Agriculture Imagery Program 2015.

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Wilcox Oil Company Superfund Site
Bristow, Creek County, Oklahoma

Area	Lead PRG (mg/kg)	B(a)P PRG (mg/kg)
East Tank Farm	200	1.2
Lorraine Process Area	200	1.2
Wilcox Process Residential Area	200	1.2
Wilcox Process Industrial Area	400	1.2

Figure 3-1
Soil Exceedances above Preliminary Remediation Goals

Appendix A

Technical Memorandum on Data Gap Investigation

Appendix B

Detailed Cost Estimates